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ARMY AVIATION ADDRESSING BATTLEFIELD ANOMALIES IN REAL TIME WITH THE TEAMING AND COLLABORATION OF MANNED AND UNMANNED AIRCRAFT

by

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December 2009

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LIST OF ACRONYMS AND ABBREVIATIONS

AMBL	Air Maneuver Battle Laboratory
AWAP	Airborne Wireless Access Point
AWT	Attack Weapons Team
BCT	Brigade Combat Team
BDA	Battle Damage Assessment
BN	Battalion
C2	Command and Control
CAB	Combat Aviation Brigade
CAS	Close Air Support
CDR	Commander
CENETIX	Center for Network Innovation and Experimentation
CF	Coalition Forces
CIA	Central Intelligence Agency
C-IED	Counter Improvised Explosive Device
COE	Contemporary Operating Environment
COL	Colonel
COP	Common Operating Picture
CP	Command Post
CRP	Communications Relay Package
CTC	Combat Training Center
DIV	Division
DoD	Department of Defense
DOTMLPF	Doctrine, Organization, Training, Materiel, Leadership and Education, Personnel and Facilities
F3EAD	Find, Fix, Finish, Exploit, Access and Disseminate
FECC	Fire and Effect Coordination Cell
FMV	Full Motion Video
GCS	Ground Control Station
GMLRS	Guided Missile Launch Rocket System
GWOT	Global War on Terror
HQ	Headquarters
HUMINT	Human Intelligence
HVI	High Value Individuals

ID	Infantry Division
IED	Improvised Explosive Device
ISF	Iraqi Security Forces
ISR	Intelligence, Surveillance, Reconnaissance
JSTARS	Joint Surveillance and Target Attack Radar Systems
KIA	Killed In Action
LOS	Line of Sight
M/UM	Manned and Unmanned
MARSS	Multi-Mission Airborne Reconnaissance & Surveillance System
MDMP	Military Decision Making Process
MEP	Mission Equipment Package
MND-N	Multi-National Division North
MNF-I	Multi-National Forces Iraq
MSR	Main Supply Route
NAI	Named Area of Interest
NATO	North Atlantic Treaty Organization
NPS	Naval Postgraduate School
ODIN	Observe, Detect, Identify, and Neutralize
OEF	Operation Enduring Freedom
OIC	Officer In Charge
OIF	Operation Iraqi Freedom
OSRVT	One Station Remote Video Terminal
PBS	Public Broadcasting Service
PID	Positive Identification
QRF	Quick Reaction Force
ROE	Rules Of Engagement
RSTA	Reconnaissance, Surveillance, and Target Acquisition
SAR	Synthetic Aperture Radar
SD	Surveillance Drone
SIGINT	Signal Intelligence
SOF	Special Operations Forces
SUV	Sport Utility Vehicle
SWT	Scout Weapons Team

TAI	Targeted Area of Interest
	Teaming-Level 2
TF	Task Force
TNT	Tactical Network Topology
TOC	Tactical Operations Center
TST	Time Sensitive Targets
TTP	Tactic, Technique, and Procedure
UAS	Unmanned Aerial System
UAV	Unmanned Aerial Vehicle
UN	United Nations
U.S.	United States
USAACE	United States Army Aviation Center of Excellence
USARPAC	United States Army Pacific
USMA	United States Military Academy
USSOCOM	United States Special Operations Command
VUIT-2	Video from Unmanned Aircraft Systems for Interoperability
WIA	Wounded In Action

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I. INTRODUCTION

Imagine an insurgent fighting against the United States (U.S.) military who is a member of a terrorist organization, and the leader of an Improvised Explosive Device (IED) emplacement team. It is 2300 local time and the IED cell leader orders his small team to emplace an IED on a nearby Main Supply Route (MSR) that Coalition Forces (CF) routinely travel. He assembles his team and begins movement on foot under the cover of darkness to the MSR. The team's route of movement is along a series of canals that leads to a choke point along the MSR. The choke point has a reed line that abuts the canal and MSR providing excellent concealment for the small group of insurgents while the IED is emplaced. Upon arrival to the IED emplacement location, the site is quickly surveyed to ensure no threat exists. The team readies three, 105 mm artillery rounds and quickly emplaces the IED, rigging it to detonate from a pressure plate, which is concealed under loose dirt and gravel in the middle of the road. The team then erects a night vision capable camcorder concealed off the route to record the detonation. After the roadside bomb is emplaced, the team egresses moving stealthily through the canal network, the team members then hear a wisp and feel a rush of air, which is their last memory.

Lieutenant Colonel Adam Lange, 25th Combat Aviation Brigade (CAB) Operations Officer in 2007 during Operation Iraqi Freedom (OIF) 06-08 eloquently summarizes this event from the friendly forces perspective:

> After midnight, near a dark and quiet village in Northern Iraq, an IED emplacement team digs into the side of a road frequented by Coalition Forces unaware they are being watched from thousands of feet above. A team of armed helicopters, just kilometers away readies a pair of missiles and awaits the report that friendly forces are clear of the target to begin their initial run. Located over two hundred kilometers away, the payload operator of an Unmanned Aerial Vehicle (UAV) records the hostile activity on his screen, activates the platform's laser, and then designates the target for the manned aircraft. From the Combat Aviation Brigade (CAB) Tactical Operations Center (TOC), the payload operator communicates with both the ground force command post and the helicopter team through a relay package in the UAV. He hears that all

> friendly forces have been cleared; the next transmission heard comes from one of the helicopters. Inbound now, target acquired… Five seconds to shot… Missile away...[1]

This type of event frequently occurs on today's technologically advanced battlefield. Army aviation, and moreover, joint aviation in general, has a vast and capable arsenal of systems ready to combat insurgents in Iraq, Afghanistan, or the future battlefield.

As the above scenario suggests, this thesis examines a new concept of teaming Manned and Unmanned (M/UM) aircraft. More specifically, this thesis answers the question, "is the teaming and collaboration of M/UM aircraft, linking sensors to shooters, a more effective Tactic, Technique, and Procedure (TTP) in the conduct of Reconnaissance, Surveillance, and Target Acquisition (RSTA) operations?"

To determine the effectiveness of teaming M/UM aircraft in the conduct of RSTA operations in the Contemporary Operating Environment (COE), it is first necessary to understand what M/UM aircraft teaming is. The next chapter diagrams and discusses this innovative TTP. The following chapters provide a narrative history of the evolution of UAVs, and the technology applications they bring to bear.

Subsequent chapters include two specific case studies. The first case study is from the 25th Combat Aviation Brigade's 15-month deployment to OIF 06-08 in Multi-National Division North (MND-N), from August 2006 to October 2007, in which M/UM aircraft teaming was utilized in its infancy. This case study shows the effects of the TTP over a long period of time; in the beginning, the TTP had limited effects, but over time and with experience, significant results were achieved. The second case study is from 3rd Brigade Combat Team (BCT), 4th Infantry Division during the Battle of Sadr City in March to April 2008. This second case study examines the teaming of M/UM aircraft effects over a short period of time.

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[1] Adam Lange, "Nightly Occurrence in the 25th CAB," *Fusion Cell Briefing*, Combat Operating Base Spiecher, Tikrit, Iraq, August 2007.

Chapter V discusses a series of experiments conducted at Camp Roberts, CA in which M/UM aircraft teaming and collaboration was utilized. The objective of the experiments was to use the M/UM aircraft systems as combat enablers and relays, as well as to test the performance and distance capability of a wireless radio mesh network. Chapter VI examines M/UM aircraft teaming in the conduct of Counter Improvised Explosive Device (C-IED) operations with game theory applied. The game theory model discussed in Chapter VI can be used in combat operations to assist in resource allocation. The conclusion chapter summarizes the previous chapters. Ultimately, the conclusion analyzes whether the TTP of M/UM aircraft teaming in the conduct of RSTA operations is an effective TTP.

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II. WHAT IS M/UM AIRCRAFT TEAMING AND WHY IS IT IMPORTANT

The concept of M/UM aircraft teaming has been in the development phase over the past two decades. The Air Maneuver Battle Laboratory (AMBL) at Fort Rucker, AL, and the home of the U.S. Army Aviation Center of Excellence (USAACE), initially conceptualized the teaming of M/UM aircraft. "Since 1993 AMBL has explored advanced concepts of teaming manned and unmanned aerial platform system capabilities on the digitized battlefield in order to capitalize on the unique benefits provided by each system."[2] "The focus has been on information provided by a lethal, survivable, flexible team—an air-maneuver team—of helicopters and unmanned aerial vehicles (UAVs) conducting tactical reconnaissance missions."[3]

A significant amount of the information provided in this chapter comes from the 25th Combat Aviation Brigade's (CAB) OIF 06-08 deployment to MND-N, Iraq. The 25th CAB was one of the first CAB's to utilize the M/UM aircraft teaming TTP fully in combat. The 25th CAB took the concept of M/UM teaming from the Comanche helicopter program that the AMBL at Fort Rucker, AL conceptualized and developed. Although the Comanche program was ended and the Comanche helicopter was never fully developed or fielded, the operational concepts and technological developments from the program are now being put into use on today's battlefield.

"It may be that a military figures out how to organize itself in a new way around an already know weapon, which makes all the old ways of fighting futile."[4] The use of M/UM aircraft teaming is a TTP that has evolved over the past decade, recently coming to fruition during OIF. Manned aircraft, such as AH-64 attack helicopters or OH-58D observation helicopters, teamed with a UAV, in the conduct of RSTA operations,

[2] Anthony Jones, "UAV-Air Maneuver Integrated Operations," *Quad-a.org*, February 2001, http://www.quad-a.org/Archives/0102.htm (accessed April 7, 2009).

[3] Ibid.

[4] P. W. Singer, *Wired for War: The Robotics Revolution and Conflict in the Twenty-first Century* (New York: The Penguin Press, 2009), 181.

provides the ground commander with real-time situational awareness, as well as surveillance, target acquisition, and lethality. Many forms of M/UM aircraft teaming include, but are not limited to the following.

- A team of AH-64 attack helicopters known as an Attack Weapons Team (AWT) or a team of OH-58D scout helicopters known as an Scout Weapons Team (SWT) teamed with a UAV
- A UAV teamed with another UAV teamed to an AWT or SWT
- A fixed wing aircraft teamed with a UAV and/or an AWT or SWT

Figure 1 depicts one form of M/UM aircraft teaming. The diagram illustrates an undetected UAV (in this case, a Hunter MQ-5B) flying thousands of feet above a group of insurgents teamed with two OH-58Ds scout helicopters or SWT standing off a few kilometers from the insurgents, remaining out-of-auditory range. The UAV operator located miles away in the CAB Headquarters (HQ) develops the situation and provides real-time voice updates for the SWT and nearby ground patrol. Depending upon the Positive Identification (PID) of the insurgent, and if hostile intent is verified through the observation of the UAV, the ground commander located in the Brigade Combat Team (BCT) HQ or Battalion (BN) HQ can choose to engage the insurgents kinetically with the use of a precision, laser-guided, hellfire missile from the SWT. If the situation does not warrant an engagement, the ground commander can send the ground patrol to cordon the area. The end result of this teaming can be kinetic or non-kinetic depending on the mission and the desires of the ground commander. The level of indefinable effects from this type of teaming should weigh heavily on an insurgent who never knows when he is being watched, or if his next breath is his last.

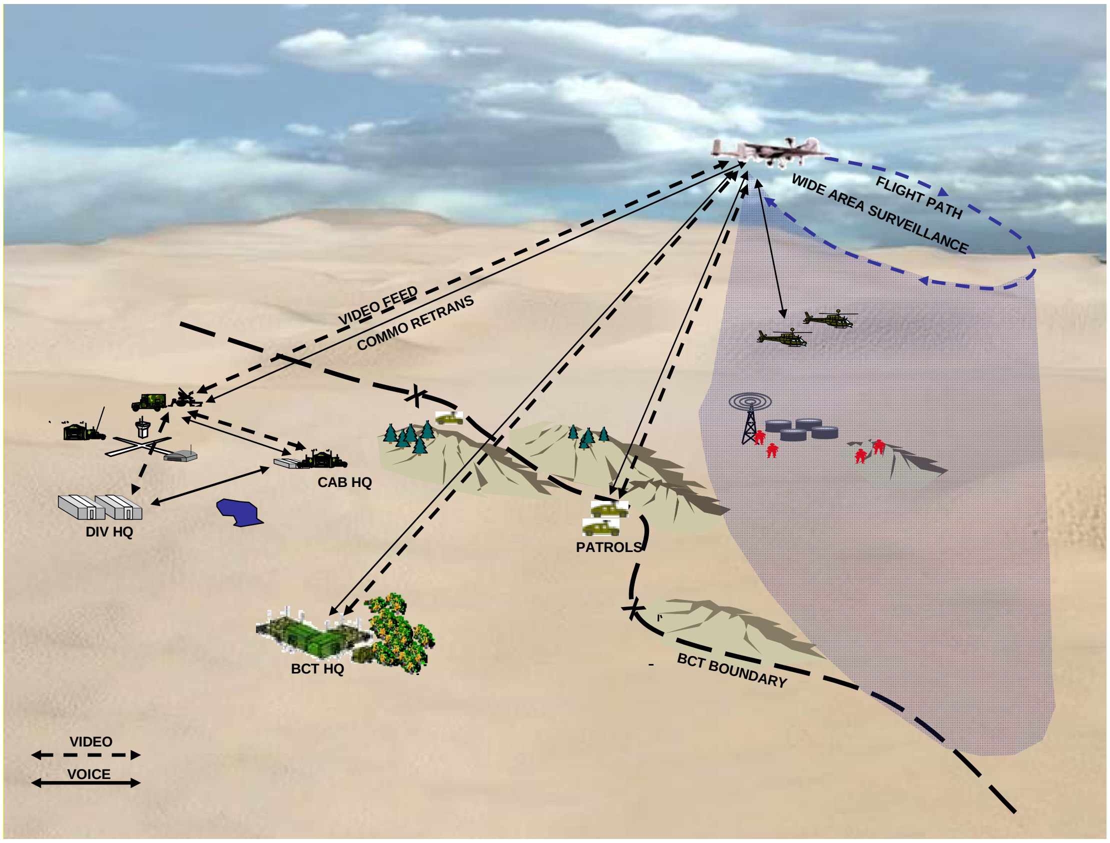

Figure 1. 25th CAB M/UM Aircraft Teaming Diagram[5]

The diagram also depicts video and voice communications through the UAV. The UAV is equipped with a Communications Relay Package (CRP) that provides for extended range of Line of Sight (LOS) voice communications. The video from the UAV, also known as Full Motion Video (FMV), is transmitted to the BN/BCT HQ, and CAB HQ. These types of capability vastly improve commanders' situational awareness and the Common Operating Picture (COP). These linkages also give the commander the ability to dynamically action both sensors and shooters, which is also commonly referred to as linking sensors to shooters.

In a recent article, "Manned-Unmanned Aircraft Teaming Making the Quantum Leap," published in the *Army Aviation Magazine*, Lieutenant Colonel Christopher Carlile and William Larese state, "The advent of remotely operated unmanned systems is rapidly

[5] M/UM Teaming Diagram, 25th CAB OIF 06-08.

emerging as a preferred method for supporting dangerous missions in today's conflicts."[6] This type of remote sensor greatly reduces the risk to the pilots of the manned aircraft. "The teaming maximizes coordination, integration and synchronization, and reduces the likelihood of risk exposure to the manned aircraft."[7]

Other forms of M/UM aircraft teaming are not illustrated above. For example, multiple aircraft providing overarching coverage of the battle space, extending communications and control over the horizon, and linking unmanned platform to unmanned platform. This type of teaming and linkage allows commanders to hand over targets between unmanned platforms until they present the optimum opportunity in the find, fix and finish sequence.

Another form of M/UM aircraft teaming is a fixed wing aircraft that has day/night sensor/camera onboard teamed with a UAV and/or other manned aircraft, such as an AWT or SWT. The fixed wing aircraft also known as a Multi-Mission Airborne Reconnaissance & Surveillance System (MARSS) increases situational awareness overhead while providing additional command and control capability.

> In other mission sets, such as Direct Action, targets that consist of IED emplacers and Time Sensitive Targets (TSTs), such as High Value Individuals (HVIs) the MARSS is able to react quickly providing flexibility and responsiveness to the unit that it is supporting. The key is ensuring communications from ground and air shooters so that optimal situational awareness and sensor to shooter links can be maintained for effective coverage.[8]

In this teaming scenario, the UAV can act as a voice relay and/or observe another Named Area of Interest (NAI) as directed by the mission commander. The AWT or SWT are in the battle space conducting RSTA operations and on order can provide lethal effects rapidly via a laser designator from the MARSS or UAV.

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6 Christopher B. Carlile and William S. Larese, "Manned-Unmanned Aircraft Teaming Making the Quantum Leap," *Army Aviation*, October 31, 2009.

7 Ibid.

8 25th CAB, OIF 06-08, text message from a briefing, Combat Operating Base Spiecher, Tikrit, Iraq, August 2007.

The bottom-line is that "aviation, both manned and unmanned, is an integral member of the joint/combined arms team in that it conducts maneuver, maneuver support, and maneuver sustainment operations across the spectrum of conflict."[9] The key benefits from M/UM aircraft teaming are: "increased operational tempos, endurance, lethality, agility, survivability, persistent surveillance, reduced unknown and high risk factors, reliable combat information, and it puts decision makers forward."[10] No matter what the platform, M/UM aircraft teaming improves situational awareness, network capabilities, voice communications, and decreases "unduly risk for the dull, dirty, and dangerous missions."[11]

[9] *TSM-Reconnaissance/Attack Manned/Unmanned Teaming Concepts of Employment for Longbow Apache Block III and ERMP* (Final Draft) (United States Army Aviation War Fighting Center, Fort Rucker, AL).

[10] Carlile and Larese, "Manned-Unmanned Aircraft Teaming Making the Quantum Leap."

[11] *TSM-Reconnaissance/Attack Manned/Unmanned Teaming Concepts of Employment for Longbow Apache Block III and ERMP* (Final Draft).

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III. THE UNMANNED AERIAL VEHICLE (UAV) AND ITS EVOLUTION

> The pattern with unmanned planes in the early twenty-first century seems to be mirroring what happened with manned planes in the early, twentieth century.[12]

On September 11, 2001, a terrorist organization struck the heart of the U.S. by flying hijacked airplanes into the twin towers killing thousands of innocent people. The tragic attack on 9/11 pushed the U.S. to enter war, the Global War on Terror (GWOT). As history suggests with war comes military technological advances with some technologies leading what is known as a Revolution in Military Affairs. Since the beginning of the GWOT, military innovations and technology improvements have been forthcoming, particularly in the area of UAVs and UASs. The UAV, and its enabling technologies, is one of many military innovations that have come to fruition since the onset of the GWOT.

A. THE UAV HISTORY

TA wide variety of definitions exist for UAVs; however, for the purposes of this research, a UAV is "an aircraft with no onboard pilot that can be remote controlled or fly autonomously based on pre-programmed flight plans or more complex dynamic automation systems."[13] The UAV's history begins in February 1863, two years after the start of the Civil War, an inventor from New York City named Charles Perley, registered a patent for an unmanned aerial bomber. Mr. Perley designed a hot-air balloon that could carry a basket laden with explosives attached to a timing mechanism. The timer would

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[12] Singer, *Wired for War: The Robotics Revolution and Conflict in the Twenty-first Century*, 119.

[13] Thefreedictonary.com, Unmanned Air Vehicle, http://encyclopedia.thefreedictionary.com/Unmanned+Air+Vehicle (accessed November 15, 2008).

trip the balloon's hinged basket, and the explosives would drop out, igniting a fuse in the process. Both Union and Confederate forces are said to have launched Perley's balloons during the war, with limited success.[14]

Two decades after Perley's invention of the balloon aerial bomber, Douglas Archibald took the first successful aerial photographs from a large kite in 1883.[15] "The key to the timing that turns a discovery or invention into successful innovation lies in whether the laymen can envision its possibilities."[16] The kite experimenter's photographs were published and an American soldier, Corporal William Eddy, recognized the potential for a wartime application using Archibald's design.[17]

> During the Spanish-American War of 1898, Corporal Eddy took hundreds of surveillance photographs from a kite rigged with a long shutter release attached to its string. Many of Eddy's aerial photographs—the first wartime surveillance photos in history—provided critical information to American troops about their adversaries' positions and fortifications.[18]

Corporal Eddy unknowingly set the stage for UAVs during the next century. In 1917, Dr. Peter Cooper and Elmer A. Sperry, converted a U.S. Navy Curtiss N-9 trainer aircraft into the first radio-controlled UAV named the Sperry Aerial Torpedo. In 1935, the Queen Bee radio controlled UAV was developed, marking the first returnable and reusable UAV. The Queen Bee was a spruce and plywood biplane that anti-aircraft gunners in the Royal Air Force and Navy used for aerial target practice.[19]

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[14] PBS.org, "Spies that Fly: Time Line of UAVs," *Nova Science Programming on Air and Online*. November 2002, http://www.pbs.org/wgbh/nova/spiesfly/uavs.html (accessed October 20, 2008).

[15] Ibid.

[16] Alan Beyerchen, "From Radio to Radar: Interwar Military Adaptation to Technological Change in Germany, the United Kingdom, and the United States," in *Military Innovation in the Interwar Period*, ed. Williamson Murray, and Allan R Millett (Cambridge: Cambridge University Press, 1996), 265.

[17] Ibid.

[18] PBS.org, "Spies that Fly: Time Line of UAVs."

[19] Ibid.

UAV innovations continued into World War II with Nazi Germany's production of the V-1. Nazi Germany terrorized much of England with the V-1. After World War II, UAV development continued; however, many of the developments were in the form of target drones. UAVs as known today started to evolve during the Cold War era.

Figure 2 shows Master Sergeant (retired) Charles Casey (on the left) utilizing a starting cart of sorts to begin an OQ-19 drone during 1960 in Germany. The OQ-19, also known as the SD-1, was one of the first drones in the U.S. Army to incorporate a still camera with optional TV sensor. The SD-1 was launched by a rocket booster and was recovered by parachute.[20]

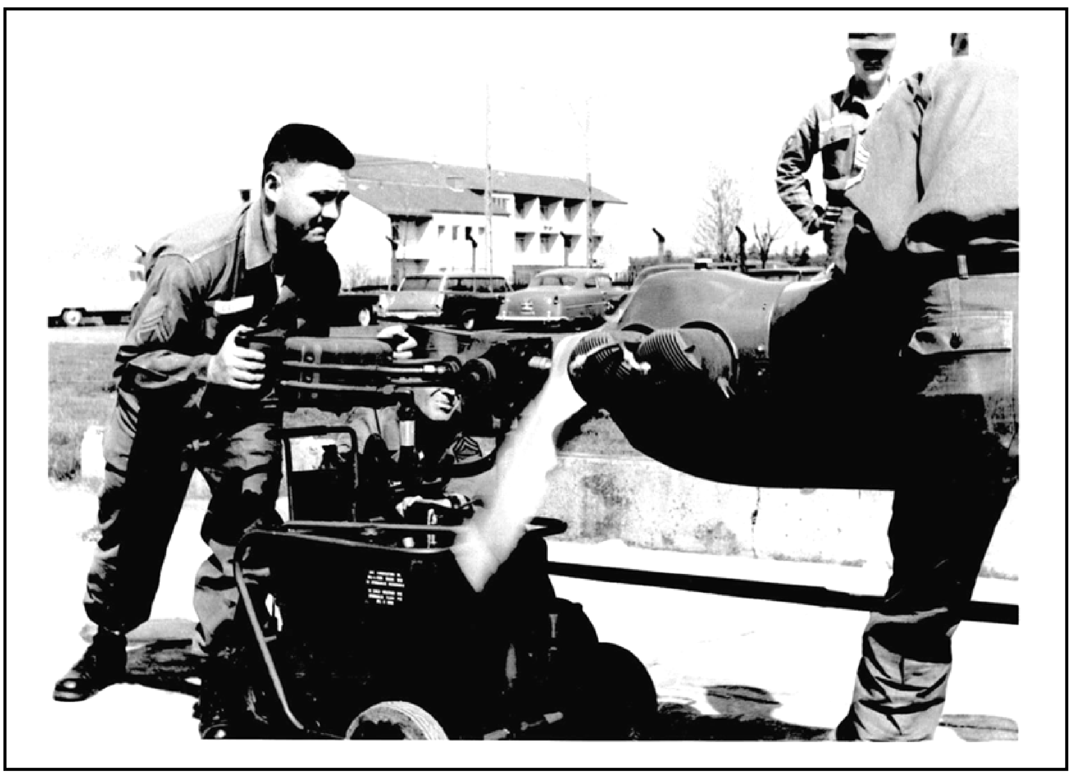

Figure 2. Picture of an OQ-19/SD-1's Starting Process[21]

[20] Charles Casey, *U.S. Army Drone in 1960*, interview by the author, September 1, 2009.

[21] Ibid.

In 1960, the U.S. Air Force began the development of combat UAVs for reconnaissance missions, the AQM-34 Ryan Firebee. "Impressed by America's AQM-34 Ryan Firebee UAV, Israel secretly purchased 12 Firebees from the U.S. in 1970, modified them, and designated them as the Firebee 1241 UAVs."[22]

> During the 1973 Yom Kippur War, the Israeli Firebee 1241s were used for reconnaissance missions and as decoys against Syria and Egypt. "On the second day of the war the Israeli Air Force deployed their fleet of armed Firebees to lead attacks against Egyptian air defenses along the Suez. The Egyptians fired their entire inventory of surface-to-air missiles at the Firebees—43 missiles in all. The Firebees successfully evaded 32 of the missiles and destroyed 11 with their Shrike anti-radar missiles.[23]

During the 1970s and 1980s, Israel aggressively developed many new UAVs, such as the Scott and Pioneer. The Scott was the first UAV capable of transmitting real-time imagery. In 1982, during the Bekaa Valley conflict, Israel used Scott UAVs to search out Syrian missile sites and entice the Syrians to activate their radars allowing bomber aircraft to destroy 17 missile sites, and continue an unhindered air campaign.[24]

Leading into the 1990s, the Pioneer UAV was used by both the U.S. and Israel. The Pioneer saw action during the Gulf War and later in the Balkans. A fitting name, the Pioneer, led to the development of the next generation of UAVs, the UAVs of the GWOT.

B. UAVS OF TODAY

UAVs of today owe their capabilities and technological advancements to the past century of conflict as summarized above. "During the 1990s, the Department of Defense (DoD) invested over $3 billion in UAV development, procurement, and operations; while reconnaissance, surveillance, and target acquisition (RSTA) were the main uses; UAVs

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22 PBS.org, "Spies that Fly: Time Line of UAVs."

23 Ibid.

24 Ibid.

were also being developed as weapons platforms."[25] The U.S. military's arsenal of UAVs has grown considerably since the beginning of the GWOT. Today's UAVs vary in capability, size and by branch of military service.

The RQ-1 Predator is a U.S. Air Force UAV developed from the aforementioned prolonged slither of technological development. The Predator has a 450-mile range, 16 hours of endurance, and can provide high definition, real time surveillance. The Predator is also equipped with infrared cameras and Synthetic Aperture Radar (SAR). "A ground team from a remote control station controls the plane either by a line-of-sight radio connection or via a satellite link."[26] The Predator is also weaponized capable based on mission requirements and can carry laser guided Hellfire missiles that can be shot autonomously or used remotely. Used by the CIA in Afghanistan after 9/11, the Predator was credited with the first Hellfire autonomous engagement from a UAV in October 2001. "The Predator UAV has been operational in Bosnia since 1995 in support of NATO, UN and U.S. operations and as part of OEF in Afghanistan and Operation Iraqi Freedom (OIF), flying over 500,000 flight hours on over 50,000 flights."[27]

Another GWOT UAV development is the U.S. Army's RQ-11 Raven. The Raven weighs less than 20 pounds, is launched by hand, can be carried in a backpack, and can fly low altitudes. The Raven has limited station time and range but is equipped with a small camera that provides real time imagery. The Raven is generally used at the company or platoon level for force protection and reconnaissance missions. "Ravens form part of the U.S. Army's 361-strong UAV contingent deployed in Iraq, which also includes Hunters and Shadows; between January and October 2007, they notched up over 300,000 hours aloft."[28]

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[25] J. W. Williams, *A History of Army Aviation: From its Beginnings to the War on Terror* (Nebraska: iUniverse, 2005), 323.

[26] PBS.org, "Spies that Fly: Time Line of UAVs."

[27] "Predator RQ-1—Unmanned Aerial Vehicle (UAV), USA," *Airforcetechnology.com*, n.d. http://www.airforce-technology.com/projects/predator/ (accessed October 20, 2008).

[28] Paul Fiddian, "U.S. Military's UAV Mission Increasing," *Armedforcesinternational.com*. February 1, 2008, http://www.armedforces-int.com/news/2008/01/02/us-mili... (accessed November 15, 2008).

The RQ-7 Shadow, tactical UAV, is larger than the Raven and is launched from a catapult type system. The Shadow has approximately 100 kilometers of range, 12 hours of station time and flies at altitudes less than 10,000 feet. The Shadow is equipped with a day/night camera that provides real time imagery to the supported unit, generally at the battalion level.

The MQ-5B Hunter UAV is another UAV that came to fruition during the GWOT. The Hunter was originally developed in the late 1990s, but not until the GWOT, was its effectiveness seen. The Hunter is a short range UAV capable of flying at ranges more than 200 kilometers from its Ground Control Station (GCS). The Hunter is equipped with a day/night camera and generally flies at altitudes of 10,000 feet or below. The Hunter is the first U.S. Army weaponized UAV. The Hunter can carry one "Viper Strike" munition that weighs approximately 40 pounds. The Viper Strike is a gravity dropped laser guided munition with less than 10 pounds of explosives. Generally, the Hunter supports brigade level operations. "Part of the adaptation to a new technology involves learning how to gauge its effectiveness."[29] On September 1, 2007 in northern Iraq, the Hunter UAV dropped a Viper Strike on two unsuspecting insurgents over-watching a roadside bomb. This historic moment marked the first ever U.S. Army UAV autonomous engagement. The Hunter UAV, and numerous other UAVs flying over the skies of Iraq and Afghanistan, have contributed to the safety of thousands of soldiers, sailors, Marines and airmen.

C. THE UAV AND ITS FUTURE

"One of the most difficult issues involved in questions of technological adaptation is not whether but rather when the innovations will have the anticipated effect."[30] Just over 100 years ago, the first UAV was a balloon rigged with explosives, and today, UAVs are capable of flying hundreds of miles, collecting intelligence from thousands of

[29] Beyerchen, "From Radio to Radar: Interwar Military Adaptation to Technological Change in Germany, the United Kingdom, and the United States," in *Military Innovation in the Interwar Period*, 297.

[30] Geoffrey Till, "Adopting the Aircraft Carrier: The British, American and Japanese Case Studies," in *Military Innovation in the Interwar Period*, ed. Williamson Murray and Allan R. Millett (Cambridge: Cambridge University Press, 1996), 193.

feet above, and autonomously engaging targets. In February 2008, Dyke Weatherington, who oversees the unmanned systems wing of the U.S. DoD said, “the Pentagon’s inventory of unmanned aerial systems has leaped from 200 in 2002 to nearly 6,000 in 2008 and the Defense Department has a $15 billion budget just for unmanned systems.”[31]

Recently, a U.S. Army AH-64 Apache attack helicopter battalion was fielded with a new Intelligence, Surveillance and Reconnaissance (ISR) DATA LINK. The data link allows the pilots of the AH-64 helicopters to view streaming, real time video from UAVs or Air Force fighter jets’ targeting pods.[32] Video from Unmanned Aircraft Systems for Interoperability Teaming-Level 2 (VUIT-2) kits also provide Apache crews with improved target acquisition, ISR collection capability, and improved situational awareness. The video can, in turn, be down-linked to the ground for simultaneous display to soldiers equipped with ground terminals.[33] The VUIT-2 kit improves the teaming of M/UM aircraft to address real time situations on today’s battlefield. The VUIT-2 kit is just one more step in the development of the next generation of UAVs and M/UM aircraft teaming collaborative engagements.

Task Force ODIN is a futuristic U.S. Army Aviation task force designed, fielded and manned to defeat Improvised Explosive Devices (IED). Originally deployed to Iraq in support of OIF in the summer of 2006, the task force combines both manned and unmanned aircraft to provide real-time reconnaissance and intelligence gathering to the supported unit. Task Force ODIN’s aircraft inventory consists of C12 airplanes also known as MARSS, and the MQ-12 Warrior Alpha UAV. Both airframe types are equipped with multiple sensors for day/night reconnaissance and surveillance. The Warrior Alpha can also be modified and armed with hellfire missiles. The imagery from the manned or unmanned aircraft from Task Force ODIN is broadcast to field units via an

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[31] Anne Broache, “Army Official: UAVs are 'Unsung Heroes' in Iraq,” *CNET.com,* February 29, 2008, http://news.cnet.com/8301-10784_3-9883300-7.html (accessed November 15, 2009).

[32] M. Malenic, “Apache Unit Equipped with New ISR Data Links to Deploy in Coming Weeks,” *Defensedaily.com*. October 9, 2008, http://www.defensedaily.com/publications/c4i/4262.html (accessed November 15, 2008).

[33] Ibid.

OSRVT or One System Remote Video Transceiver.[34] Task Force ODIN's successes in support of OIF have lead to the DoD's fielding of another such task force that recently deployed to Afghanistan.

The U.S. Army is in the process of developing and fielding the MQ-1C Sky Warrior. The Sky Warrior is a variant of the Predator with increased capabilities. "The U.S. Army has stated a requirement for 11 Sky Warrior systems (each with 12 air vehicles and five ground stations), planning to deploy them with one company assigned to each of 10 divisions and one to a training unit."[35] The Sky Warrior will be a division level asset supporting BCTs and joint operations in the conduct of RSTA and ISR operations.

The UAVs of today and their enabling technologies should be considered one of the top military innovations of the GWOT. The evolution of technology and the UAV over the last century has been nothing short of science fiction meeting reality on the battlefield. Consider the advancements from Perley's Balloon Aerial Bomber, to the SD-1, Firebee, Pioneer, Hunter, and today's Predator. The evolution of the UAV has had a tremendous impact on the battlefield, and its potential in the future is unbounded and limited only to the imagination.

[34] CASR.ca, "Canadian American Strategic Review 2008. Background Comparison, U.S. Army Aviation, Task Force Odin," http://www.casr.ca/bg-army-aviation-tf-odin.htm (accessed November 15, 2008).

[35] Jane's Defense Equipment and Technology, "Jane's Unmanned Aerial Vehicles, MQ-1C Sky Warrior," http://www.janes.com (accessed October 6, 2009).

IV. CASE STUDIES

> Teaming UAS with manned aircraft systems provides enhanced operational fires and maneuver efforts while extending the command and control and intelligence capabilities for the commander. Teaming provides force protection, reconnaissance, and surgical lethality to the maneuver force. It can operate at extended depth and has the flexibility to rapidly adjust to changing conditions. Manned aircraft make required decisions and reduce sensor-to-shooter time in dealing with fleeting targets, especially in constrained Rules Of Engagement (ROE) environments.[36]

A. BATTLE OF SADR CITY, CASE STUDY

What follows are notes of the major elements of General Petraeus' remarks referencing the Battle of Sadr City, Iraq in March-April 2008, which he briefed to the U.S. Military & Foreign Policy World Affairs Council in Seattle, WA on July 8, 2009. C-SPAN later aired this briefing.[37]

> After Prime Minister Maliki directed the operation in Basrah against the Jaysh al Mahdi in March 2008, the militia also erupted in the Sadr City district of Baghdad, pounding the International Zone with as many as 20 volleys of multiple rockets each day.
>
> Over the course of about a week, we managed to assemble the platforms depicted here and emplace the various supporting architectures and pipes to pull it all together. In this case, assets, and the responsibility to employ them, were pushed to a single brigade commander, Colonel (COL) John Hort of 3rd Brigade, 4th Infantry Division. COL Hort had a variety of assets at his disposal: mechanized infantry in Bradleys, Stryker infantry and cavalry, M1 tanks, Special Operations Forces (SOF) snipers, Iraqi Conventional Forces, Human Intelligence (HUMINT), Counter-fire radars, precision artillery, Guided Missile Launch Rocket Systems (which allowed us to hit a meeting of Special Groups leaders right across the street from a hospital without even breaking a window in the hospital).

36 FM 3-04.155 (Draft), Army Unmanned Aircraft System Operations.

37 David Petraues, C-SPAN video briefed at the U.S. Military & Foreign Policy World Affairs Council, Seattle, WA, July 8, 2009.

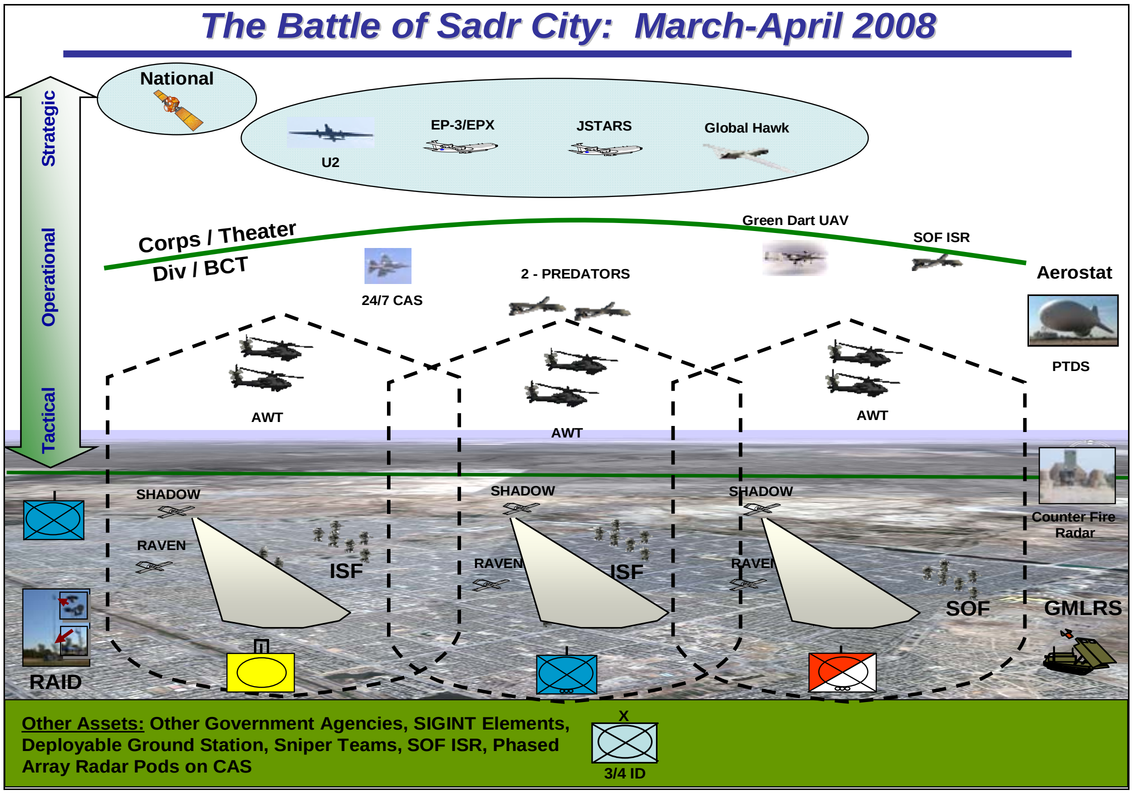

Figure 3. The Battle Sadr City March-April 2008, 3BCT/4th ID[38]

"This ISR slide depicts the evolution of how we fight; it graphically depicts the Battle of Sadr City, and how far combat has evolved from the slugfest that was the Battle of Fallujah."[39]

> On top of all this, we arrayed all the ISR assets depicted here. Supporting this one brigade, 24/7, were 2 Predators (armed with Hellfire missiles), Shadow and Raven UAVs, aerostat blimps with optics, Raid towers, 3 air weapons teams (of 2 AH64 Apaches each), and 2 additional UAVs with special capabilities. Also in support was Close Air Support (CAS), and the national, strategic intelligence platforms depicted at the top of the slide. We gave the brigade more ISR than any unit in history.
>
> The BCT Commander's (CDR) Command Post (CP) had feeds for each ISR (screen displays for each platform with chat rooms underneath), and we gave him the authority to pull the trigger—authorities that in some

[38] Petraues, C-SPAN video briefed at the U.S. Military & Foreign Policy World Affairs Council.

[39] Ibid.

cases had been held as high as Multi-National Forces Iraq (MNF-I)… This required an enormous amount of real-time coordination; for example, those seeing a feed in the CP conversed on chat rooms with the payload operators flying the assets at Nellis AFB, while at the same time analysts at Ft. Meade, Ft. Gordon, Germany, and the United Kingdom were also providing feedback. Those on the ground could tell the operator of the optic on an Aerostat where to focus. This type of C2 has enormous implications for signals intelligence and overlaying HUMINT; we found new applications every month.

This brigade leveraged all these assets to kill 77 mortar and rocket teams. The brigade killed 780 militia members. A typical action might be: a militant launches a rocket; it is picked up by counter-fire radar; a UAV gets "eyes on" the point of origin and tracks the militant through the city to a car trunk that serves as a weapons cache; the weapons cache is hit with a hellfire. We would also park a UAV over known locations, because they would reuse locations and withdraw quickly; we also had Apaches circling the city looking at NAIs. We started responsive fusion of systems to start being predictive, focused on known or expected rocket launch sites. We targeted the 8 Special Groups leaders, killing one, wounding another, and killing the 3 special assistants of another (who made the mistake of borrowing their leader's car); after which, the remaining Special Groups leaders fled to Iran.

In the southern quarter of Sadr City, our troopers had to fight and wrest away that portion of the city and every night work to extend the T-Wall a couple hundred meters. We still used conventional operations, including rifle and tank fire, but the enablers gave us an enormous edge.

The key is not to overload a CDR with too many assets—pushing resources and the authorities to employ them to the proper level. This is a skill our leaders have learned through experience, and all the ISR hardware in the world is useless without skilled operators and commanders on the ground who know how to leverage it. Good C2 of these systems is important, as decision time is often the limiting factor in their use. This is about developing human capital over the course of years. C2 of these ISR assets is tough to replicate in training scenarios or in Combat Training Centers (CTC); it is outstripping our ability to model it. As remarkable as the aggregation of capabilities on this battlefield is the evolution of the sensory piece of the battlefield and of the ability of commanders to leverage it all.

The Battle of Sadr City, March–April 2008, was a remarkable illustration of how effective the teaming of M/UM aircraft can be in the conduct of RSTA operations. The

end result of 780 militia members killed, and a safe and secure Sadr City, was a remarkable accomplishment; understanding of course, that the C2 of the entire, complex operation was probably the second biggest achievement of 3BCT/4th ID.

B. 25th COMBAT AVIATION BRIGADE, OPERATION IRAQI FREEDOM 06-08, CASE STUDY

> Cooperative operations enable the aviation or ground commander to develop the situation, and conduct decisive, integrated air-ground operations to close with and destroy the enemy through fire and maneuver. Cooperative engagements extend the tactical reach of maneuver forces while furnishing the commander with immediate reinforcing fires. During close combat operations, cooperative engagements enable precision direct and indirect fires integrated into the ground scheme of maneuver.[40]

In a 25th CAB published article, Colonel A. T. Ball discusses the operational impact of Unmanned Aerial Systems (UAS). The 25th UAS Company focused on M/UM teaming during OIF 06-08, creating dynamic linkages between "sensors" and "shooters," and presented opportunities where UAS "sensors" developed the enemy situation and allowed the "shooters" to standoff at safe distances.[41] COL Ball later describes that after "sensors" established hostile intent and positive identification, "shooters" were then able to engage the enemy either through autonomous means or through remote laser designation. The 25th UAS broadened the use of unmanned assets from the traditional ISR process to a more operational RSTA focus in the maneuver fight.[42]

> Capabilities of Army UAS have evolved from a theater intelligence asset to primarily tactical roles, such as surveillance, reconnaissance, attack, targeting, communications relay, convoy overwatch, and cooperative target engagement through M/UM aicraft teaming. The Army is employing UAS as an extension of the tactical commander's eyes to find,

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40 FM 3-04.155 (Draft), Army Unmanned Aircraft System Operations.

41 A. T. Ball, "25th Unmanned Aerial Systems Company Always Watching over the Iraqi Skies," *Newsblaze.com*, October 2007, http://newsblaze.com/story/20071004115810tsop.nb/topstory.html (accessed January 25, 2009).

42 Ibid.

fix, follow, facilitate, and finish targets. Army UAS missions are integrated into the maneuver commander's mission planning, at the start, as a combat multiplier in the contemporary operational environment.[43]

During the 25th CAB's 15-month deployment to MND-N Iraq, it supported five BCTs with RSTA assets to include AH-64s, OH-58Ds, UASs, and other platforms from TF ODIN. Over the course of the deployment, the M/UM aircraft teaming TTP was utilized in the conduct of RSTA operations resulting in 157 "sensor to shooter" engagements with a Battle Damage Assessment (BDA) of 532 insurgents either Killed In Action (KIA), Wounded In Action (WIA), or detained. Additionally, the CAB had 697 "shooter" engagements with 1,757 insurgents either KIA, WIA, or detained.

Major John Herrman, the Officer in Charge (OIC) of the Fires and Effects Coordination Cell (FECC) for the 25th CAB during the OIF 06-08 deployment, conducted a statistical analysis of the CAB's shooter and sensor to shooter engagement data set. The purpose of the analysis was to, "provide an information brief through statistical analysis depicting the process, measure, efficiency and packaging of Manned & unmanned aerial platforms of the 25th CAB during OIF 06-08, and how this integration has developed a more effective method to find and efficient process to engage the enemy."[44]

Major Herrman began his analysis by defining the terms listed below.

- **Sensor:** An un/manned system that has the ability to detect targets and relay this information to other systems to improve situational awareness
- **Shooter:** An aircraft, which can engage the enemy with munitions, such as Attack Aviation, CAS, or Hunter-Viper Strike
- **Sensor–Shooter:** The pairing of a sensor platform with a shooter to facilitate engagement of the enemy
- **Enabler:** Other systems, which can interface with sensors and/or shooters, and by doing so, improve the overall performance
- **Engagement:** Taking action on the enemy—regardless of enemy size or number of attacks by the aircraft

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[43] Jeffery Kappenman, "Army Unmanned Aircraft Systems: Decisive in Battle," http://www.ndu.edu/inss/Press/jfq_pages/editions/i49/10.pdf (accessed October 16, 2009).

[44] John Herrman, Documenting TTPs Statistical Analysis, PowerPoint presentation for the 25th Combat Aviation Brigade from Operation Iraqi Freedom 06-08, Tikrit, Iraq, October 2007.

- **BDA:** The total number of enemy KIA/WIA/Detained in an engagement
- **Employment Type:** The process in which the target is engaged (Shooter, Sensor-Shooter)
- **Employment Efficiency:** The ratio of number of engagements with at least one enemy KIA/WIA/Detained divided by the total number of engagements
- **RSTA:** Reconnaissance, Surveillance, and Target Acquisition. Used by the 25th CAB when referring to the employment of UAVs

Major Herrman explained that, "repeated observations of shooter and sensor-shooter engagements appeared to show sensor-shooter engagements growing in efficiency."[45] The observations he studied for statistical significance were in two categories, employment type, and employment efficiency. He compared the sensor to shooter number of engagements and BDA over time to the shooter number of engagements and BDA over time (see Figure 4).

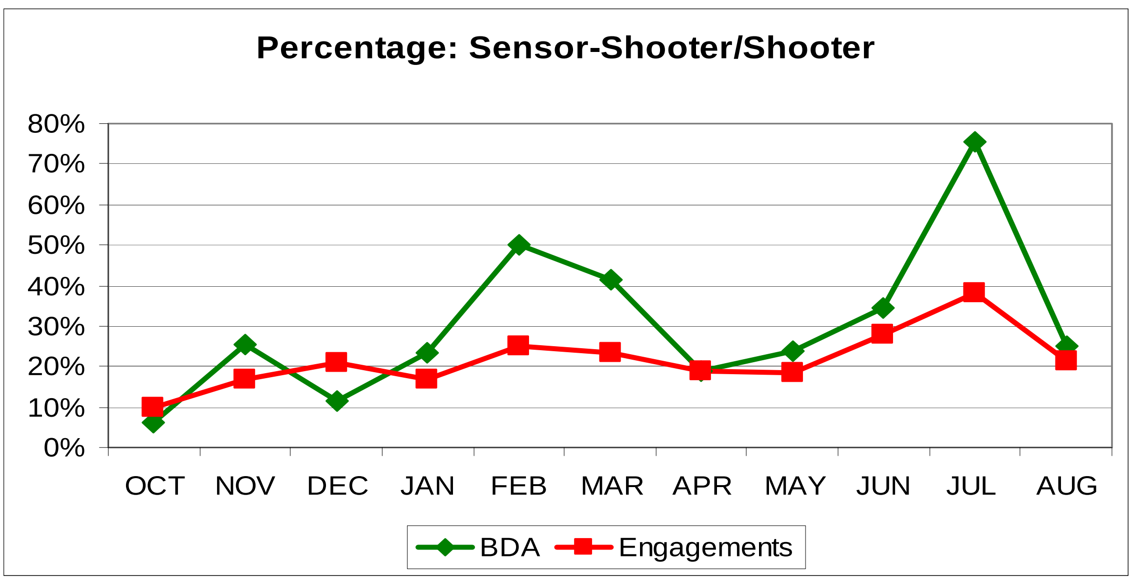

Figure 4. 25th CAB Sensor to Shooter & Shooter Engagements and BDA over Time[46]

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[45] Herrman, Documenting TTPs Statistical Analysis, PowerPoint presentation for the 25th Combat Aviation Brigade from Operation Iraqi Freedom 06-08.

[46] Ibid.

Figure 4 shows that BDA and engagement percentage trend steadily increased, which is significant given the ratio of sensors to shooters operating on the battlefield at a given period. Major Herrman stated, "it's important to note that while the percentage of sensor to shooter engagements increased overtime, there was no reduction in the amount of per shooter engagements, in other words the 25th CAB didn't swap one method for another."[47]

Refining his analysis, John Herrman continued with an efficiency analysis measurement. He measured opportunities made and missed defined below as each separate instance the enemy was positively identified.

- An opportunity made was an engagement where at least one enemy was KIA/WIA/Detained—enemy removed from the battlefield
- An opportunity missed was an engagement in which no enemy was KIA/WIA/Detained—the enemy lives to fight another day

Major Herrman then calculated the efficiency ratio Opportunities Made/Opportunities. See Figures 5 and 6 for a graphical depiction of the results.[48]

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[47] Herrman, Documenting TTPs Statistical Analysis, PowerPoint presentation for the 25th Combat Aviation Brigade from Operation Iraqi Freedom 06-08.

[48] 25th CAB, OIF 06-08, text message from a briefing, Combat Operating Base Spiecher, Tikrit, Iraq, August 2007.

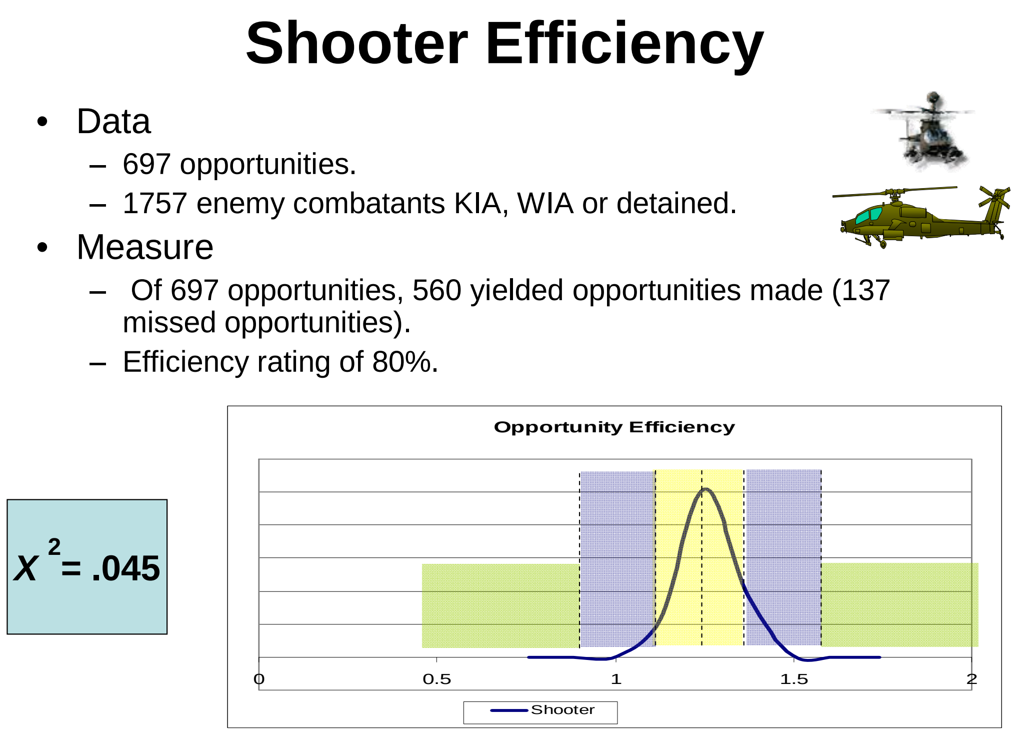

Figure 5. 25th CAB, OIF 06-08 Shooter Efficiency[49]

Figure 5 shows there were 697 shooter engagement opportunities, of which 560 were made or successful and 137 opportunities were missed. The resultant was an efficiency ratio of 80 percent and BDA of 1,757 enemy combatants removed from the battlefield.

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[49] Herrman, Documenting TTPs Statistical Analysis, PowerPoint presentation for the 25th Combat Aviation Brigade from Operation Iraqi Freedom 06-08.

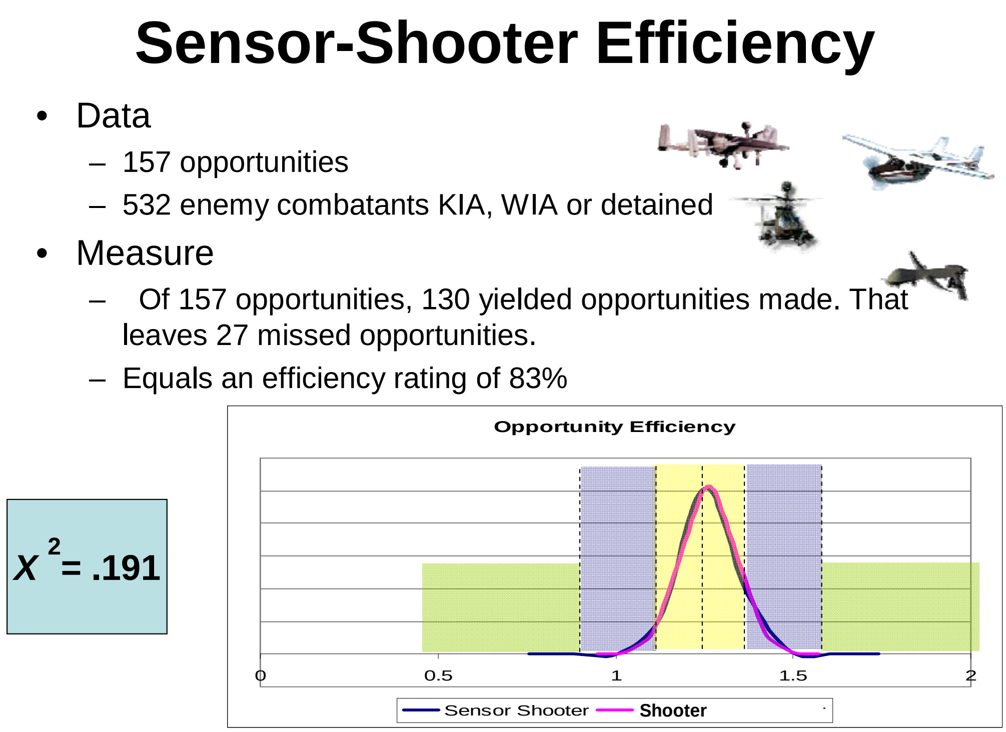

Figure 6. 25th CAB, OIF 06-08 Sensor to Shooter Efficiency[50]

Figure 6 shows there were 157 sensor to shooter engagement opportunities, of which 130 opportunities were made or successful and 27 were missed. The resultant was an efficiency ratio of 83 percent and BDA of 532 enemy combatants removed from the battlefield.

> The teaming of manned platforms with UAS is fast becoming the standard in the Army rather than the exception. M/UM teaming extends the shooter's eyes on target by linking UAS sensors to the manned platforms. UAS with laser-designator payloads have the ability to laser designate for attack platforms as part of a cooperative engagement, providing maximum standoff distance for the manned aircraft and increasing survivability. UAS are also used to cross cue time-sensitive targets and/or provide overwatch while commanders determine the optimal manner in which to prosecute a specific target.[51]

[50] Herrman, Documenting TTPs Statistical Analysis, PowerPoint presentation for the 25th Combat Aviation Brigade from Operation Iraqi Freedom 06-08.

[51] Kappenman, "Army Unmanned Aircraft Systems: Decisive in Battle."

In summary, the 25^{th} CAB's sensor to shooter linkage made each opportunity more lethal by over three percent. If resources were abundant, and the 25^{th} CAB utilized the teaming of M/UM in every engagement opportunity, hypothetically and statistically, 53 additional enemy combatants would have been removed from the battlefield. Understanding that for the 25^{th} CAB, the use of M/UM aircraft teaming was a TTP that grew in its effectiveness over time, the three percent mentioned above could be much greater with continued implementation.

V. MANNED AND UNMANNED AERIAL SYSTEMS AND NETWORK-CENTRIC COLLABORATION: A LOOK AT TECHNOLOGY APPLICATIONS FOR AERIAL SYSTEMS AS THEY RELATE TO TODAY'S WARFARE OPERATIONS

Over the course of 2009, a team at the Naval Postgraduate School (NPS) working through the Center for Network Innovation and Experimentation (CENETIX), conducted a series of experiments to develop and analyze the use of Manned and Unmanned (M/UM) aircraft teaming and network centric collaboration as enablers in support of today's warfighters. The experiment culminated on November 15, 2009 with significant success.

CENETIX is a unique organization in that it utilizes academic researchers coupled with contractors and other agencies to explore frontiers of self-organizing tactical networking and collaboration. "It provides students and faculty with opportunities for interdisciplinary study of agile adaptive wireless networks, network-controlled unmanned vehicles, sensors, intelligent agents, and situational awareness platforms."[52] Primarily, CENETIX conducts "several national level field experimentation campaigns, including the Tactical Network Topology (TNT) program, run in cooperation with U.S. Special Operations Command (USSOCOM)" at Camp Roberts, CA.[53]

> The TNT experimentation process with USSOCOM is focused on both technologies associated with networking and the human aspects of networked forms of organization. Technologies investigated have included network controlled Unmanned Aerial Systems (UAS), various forms of multiplatform wireless networking, mesh networked tactical vehicles, deployable operations centers, collaborative technologies, situational awareness systems, multi-agent architectures, and management of sensor-

[52] Center for Network Innovation and Experimentation, Naval Postgraduate School, http://cenetix.nps.edu/cenetix/ (accessed November 16, 2009).

[53] Ibid.

> unmanned vehicle-decision maker self-organizing environments… The focus has been on both adapting both emerging and commercially available technologies to military requirements…[54]

Within the broad spectrum of NPS/USSOCOM experiments, the NPS-led M/UM aircraft teaming series of experiments conducted at Camp Roberts, CA included students and professors from NPS and contractors, such as AvWatch, WinTec, Persistent Systems, and the Software Engineering Institute from Urban Robotics. The experiments' objective was to explore network-defined constraints associated with M/UM aircraft system collaboration in the environment of mesh broadband wireless networking between the aircraft systems and ground maneuver units. Subject to network constraints, correspondingly, the tactical scenario for the experiment was designed to support the concept of Observe, Detect, Identify, and Neutralize (ODIN) Improvised Explosive Devices (IED) that plague U.S. forces in Afghanistan and Iraq. The primary task of the experiments was to analyze the wireless broadband networks performance and distance capability via a manned aircraft and Unmanned Aerial Vehicle (UAV) through wave relay radios (see Figure 7) during a simulated counter-IED scenario. Additionally, the experiment sought to hand-off the day/infrared camera sensor from the manned aircraft payload operator to an operator with the ground maneuver unit.

[54] Alex Bordetsky and David Netzer, "TNT Testbed for Self-Organizing Tactical Networking and Collaboration," Center for Network Innovation and Experimentation (CENETIX), Naval Postgraduate School, http://cenetix.nps.edu/cenetix/documents/TNT_Testbed-BordetskyNetzerRev percent204.doc (accessed November 25, 2009).

Figure 7. Wave Relay Radio, product of Persistent Systems, is an "off the shelf, mobile ad hoc networking system available in a man portable form, providing a wearable wireless connectivity solution for users on the move."[55]

Colonel A. T. Ball, Chief of Staff, United States Army Pacific, comments on the experiments.

> Developing a way for the system to hand off control of the manned aircrafts' sensor to the ground unit is consistent with the goals of furthering our air to ground integration as part of the C-IED fight. This experiment is of significant operational importance and draws upon the Tactics, Techniques, and Procedures (TTP) and enhanced air to ground integration that came to fruition during Operation Iraqi Freedom 06-08. These sort of TTPs played a large role in Task Force ODIN's success and further advances in this domain will add great value to our warfighters in the C-IED fight.[56]

Figure 8 diagrams a manned aircraft with a wave relay radio installed coupled with a day/infrared camera sensor receiving broadband wireless data from a directional antenna stationed and fixed at the Tactical Operations Center (TOC). In turn, the manned aircraft, operated by AvWatch, and orbiting thousands of feet overhead, was transmitting network data to the ground unit via a look down antenna. For experimentation purposes, the ground unit was a black Sport Utility Vehicle (SUV) manned by two personnel. The

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[55] Persistent Systems, http://www.persistentsystems.com/ (accessed November 16, 2009).

[56] Arthur T. Ball, e-mail message to the author, November 10, 2009.

SUV was also configured with a wave relay radio that received the manned aircraft's signal and displayed the received data on a laptop. The laptop in the SUV was configured with software and a video game like controller provided by AvWatch that enabled the passenger in the SUV to monitor the manned aircrafts sensor video, as well as the capability to control the manned aircraft's camera sensor.

Figure 8. Pictorial of the Experiment.

Figure 9 depicts a manned aircraft receiving and transmitting broadband wireless data to and from the TOC. The manned aircraft is also broadcasting data to the ground unit or Quick Reaction Force (QRF). The data streaming over the network includes Full Motion Video (FMV) from the aircrafts sensor.

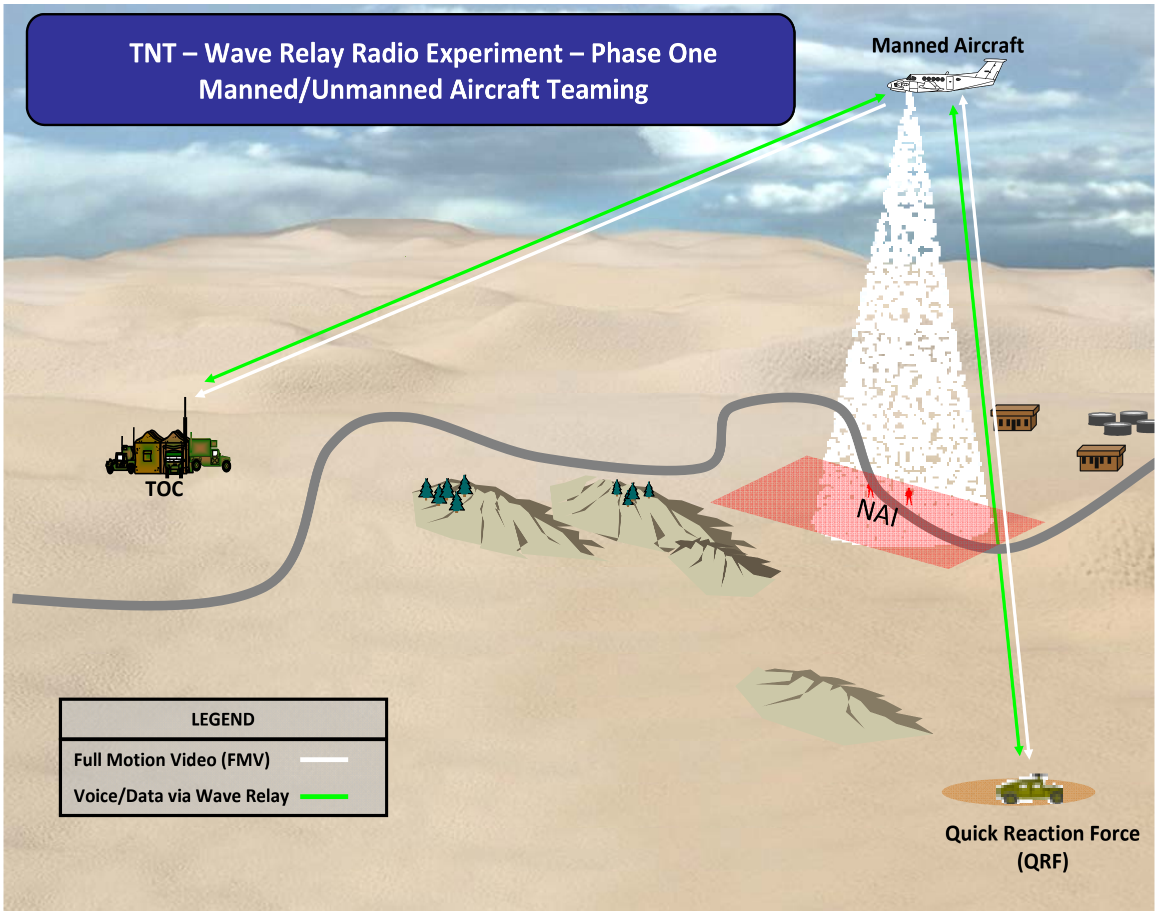

Figure 9. Phase One of the TNT M/UM Aircraft Teaming Experiment

Phase one of the experiment utilized the manned aircraft as a relay for the ground vehicle/QRF depicted as the Command and Control (C2) vehicle. The C2 vehicle, while on the move, was able to observe the manned aircrafts FMV. Distances of up to 15 miles were obtained; however, further distances can be achieved with a vehicle-mounted directional antenna. Phase one of the experiment also tested the distance of the network signal from the TOC to the manned aircraft. The manned aircraft was flying at 8500' Above Ground Level (AGL) with a directional antenna resulting in 27 miles of connectivity; achieving a much greater distance than previous experiments.

Figure 10. Phase One Experimentation Depiction Results.

Phase two, as depicted below, utilized the manned aircraft as a relay from the TOC to a Raven UAV to the QRF. The manned aircraft orbited at 5000’, while a Raven Airborne Wireless Access Point (A-WAP) UAV orbited at 400’ AGL above the QRF. The QRF vehicle moved to an area of low terrain with high terrain surrounding the vehicle. The QRF then measured the signal strength of the network and determined that the Raven UAV as a relay improved the signal strength by approximately 40 percent. The QRF vehicle operator was then able to take control of the manned aircrafts sensor.

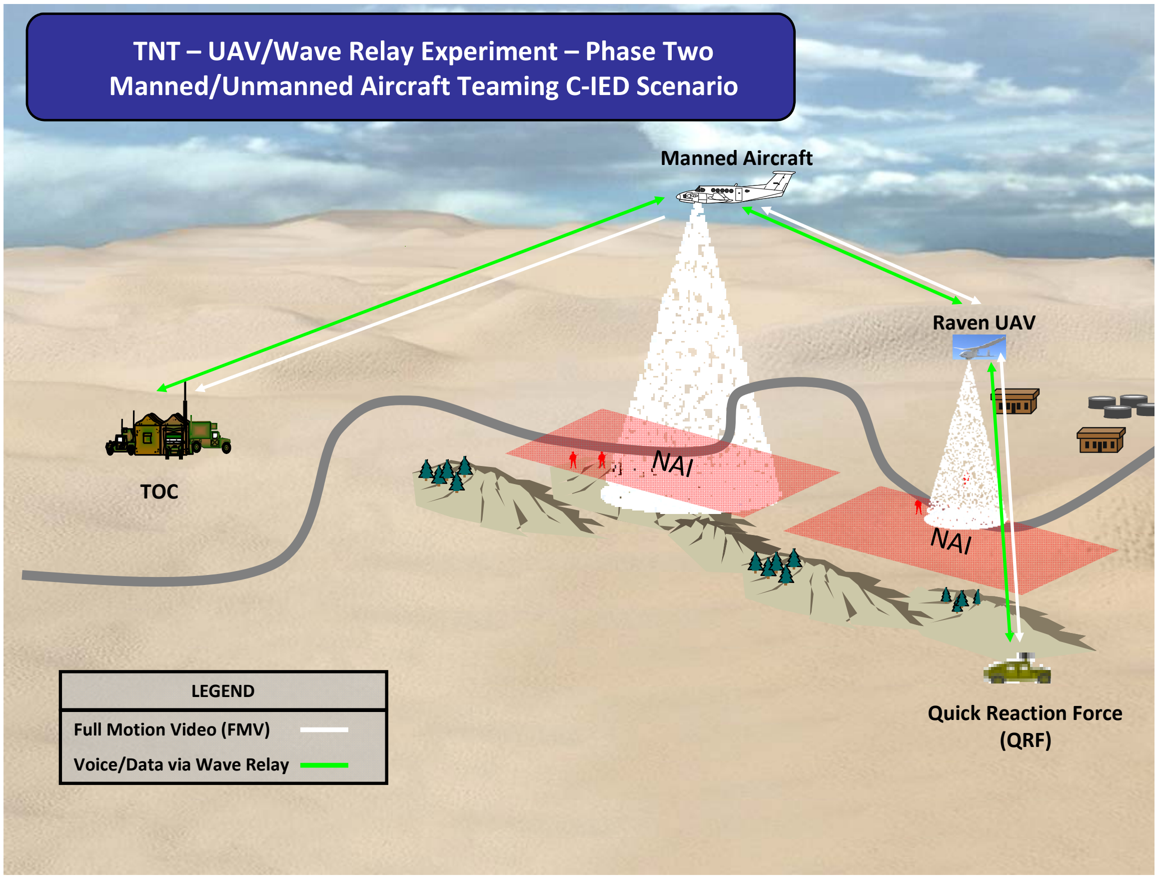

Figure 11. Phase Two of the TNT M/UM Aircraft Teaming Experiment

Overall, this phase of the experiment was a major success. Some of the significant lessons learned during the experiment were the following.

- Antenna selection makes a significant difference; if available, use directional antennas
- The Raven UAV as a relay would be better suited with both a top and bottom antenna
- All users should be on the same sub-net setting
- Add amplifiers for more through put and better performance
- VOIP on the wave relay is essential and would significantly benefit the user
- Channel width—use a smaller channel width for greater distances and a more reliable data link

"Collaborative technologies are leading the revolution in military affairs as they help commanders and warfighters realize long-sought capabilities in the network-centric force."[57]

In summary, by teaming M/UM aircraft in a network centric and collaboration environment, the ground commanders situational greatly improves. The experiments allowed the identification of network associated constraints for configuring the ad hoc mesh network by changing the roles between M/UM aircraft as relay and surveillance nodes. As demonstrated in these experiments, this type of ad hoc, mesh networking, with wave relay radios via M/UM aircraft, is an efficient solution helping to overcome steep terrain and provides an over-the-horizon capability to the warfighter on the ground, which could be a solution to the problems U.S. soldiers are facing in Afghanistan. Continued research and experimentation in this domain benefits the warfighters, civil services, and homeland security in the United States.

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[57] Robert K. Ackerman, "Collaboration Enables Technological Slight of Hand," *Signal Magazine* (May 2006): 45–50.

VI. GAME THEORY—MANNED AND UNMANNED (M/UM) AIRCRAFT TEAMING C-IED OPERATIONS VERSUS THE IED PROBLEM SOMEWHERE IN IRAQ OR AFGHANISTAN

A. THE DILEMMA

The IED problem that exists in Iraq and Afghanistan continues to plague friendly forces. In a recent report, Secretary of Defense Gates "pledged more equipment and surveillance to protect troops against the roadside bombs… 'We are in the process of putting significant additional surveillance and reconnaissance capabilities in Afghanistan'." Gates also said, "Additional material worked well for us in Iraq in dealing with the IED problem. We're hoping it's going to work in Afghanistan as well."[58] The report also stated, "at least 306 coalition troops have lost their lives since the beginning of the year, up from 294 in 2008. Many of the casualties have been the result of roadside bombs."[59]

The game question to be analyzed and modeled is, given a particular section of a Main Supply Route (MSR) where IED activity has been high, either in Iraq or Afghanistan, where should friendly forces focus reconnaissance efforts? Additionally, on what Targeted Area of Interest (TAI) should the insurgents focus their efforts?

B. THE GAME

This game takes place somewhere in Iraq or Afghanistan and occurs on a daily basis (24 hours a day) along a MSR frequently traveled by Blue Forces (friendly forces). Red Forces (insurgents) continually disrupt the movement of troops and supplies, and sometimes injure Blue Forces by emplacing and detonating IEDs along the MSR.

Blue Forces have multiple reconnaissance resources both manned (scout and attack helicopters) and unmanned (Unmanned Aerial Vehicles—UAVs) aircraft to

[58] Shaun Tandon, "Gates Vows Aid against Afghan Roadside Bombs," *Jieddo.dod.mil*, August 31, 2009, https://www.jieddo.dod.mil/article.aspx?ID=611 (accessed September 7, 2009).

[59] Ibid.

Observe, Detect, Identify, and Neutralize (ODIN) IED emplacers along the route. Blue Forces want to maximize the use of resources to support other priorities across the battle space. Blue Forces want to ***minimize*** Red Forces' successful IED attacks and ***maximize*** observation of IED emplacers.

Red Forces have multiple IEDs, but due to restricted terrain and other factors, can only target one area. Red Forces want to maximize the use of their resources to support other priorities across the battle space. Red Forces want to ***maximize*** successful IED attacks against Blue Forces.

Figures 12–14 depict the game. The author uses three separate but linked scenarios. Scenario one (Figure 12) illustrates Blue Forces observing one of four Named Area of Interest (NAI) with a UAV. Red Forces target one of four TAIs with IEDs. Scenario two (Figure 13) illustrates Blue Forces observing one of four NAIs with an SWT or AWT. Red Forces target one of four TAIs with IEDs. Scenario three (Figure 14) illustrates Blue Forces observing one of four NAIs with a M/UM aircraft team (UAV and SWT or AWT). Red Forces target one of four TAIs with IEDs.

It is important to understand the difference between each NAI/TAI and the numerical values associated with them. NAI/TAI AC is an open area, which allows for good observation by Blue Forces, and in turn, makes it high risk for Red Forces. NAI/TAI BC is located in rugged terrain making it more difficult for Blue Forces to observe, and thus, allowing Red Forces freedom of movement and adequate cover and concealment. NAI/TAI BD is located in an open area, but has high terrain adjacent to it, making the route observable by Blue Forces; however, the high terrain makes for adequate cover, concealment, and over watch for Red Forces. NAI/TAI AD is located in an urban environment; thus, making it difficult for Blue Forces to observe due to battlefield clutter, debris along the route, and constant vehicular traffic and pedestrians. Red Forces can target TAI AD with freedom of maneuver, and thus, is low risk.

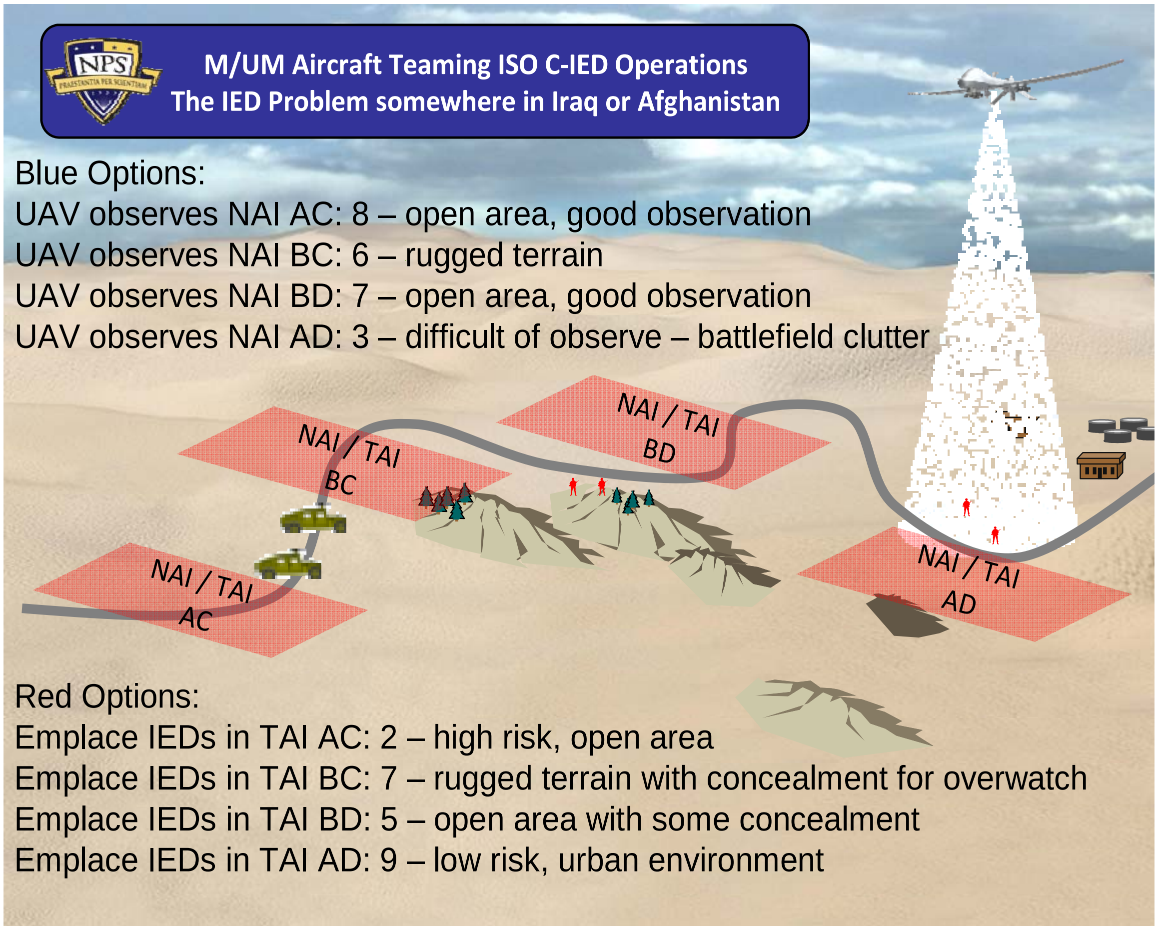

Figure 12. UAV (Blue Forces) versus IED emplacers (Red Forces)

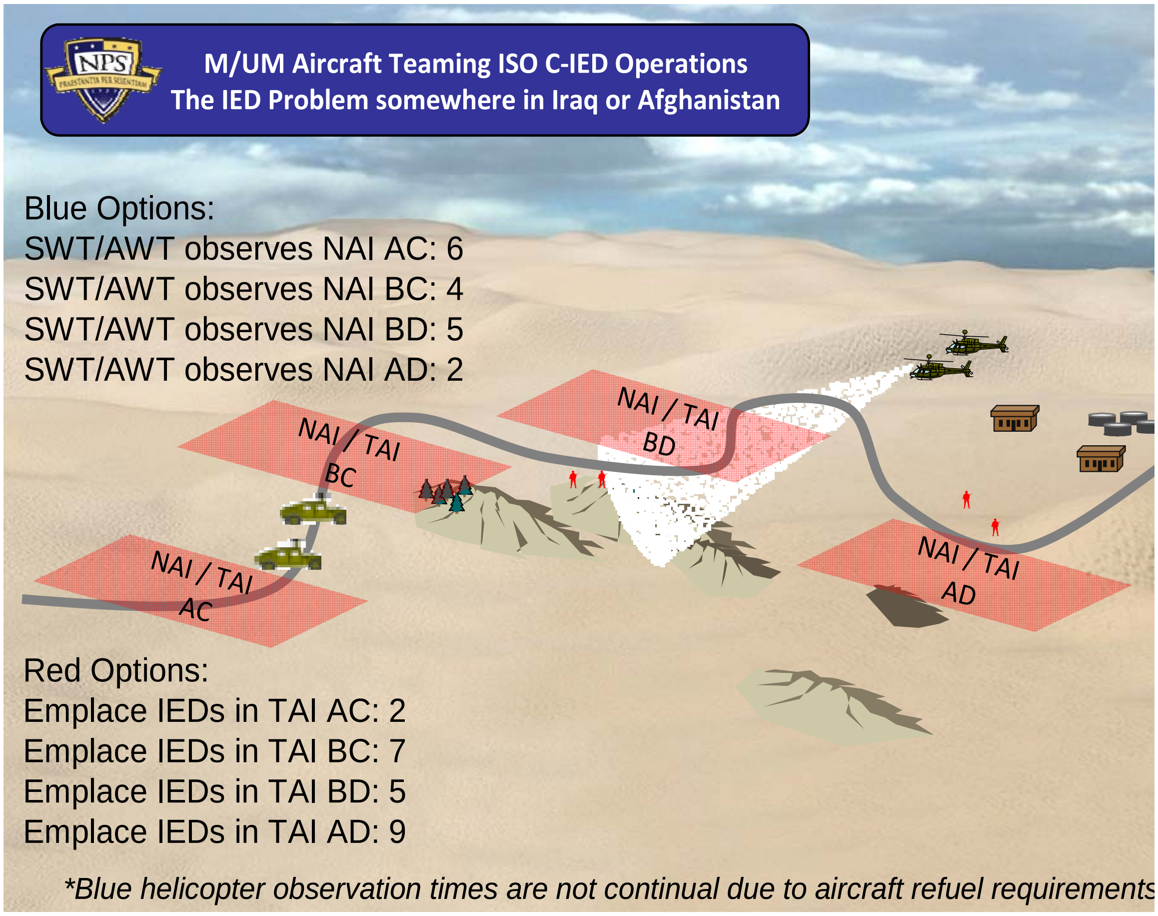

Figure 13. Scout Weapons Team (SWT) or Attack Weapons Team (AWT) versus IED emplacers

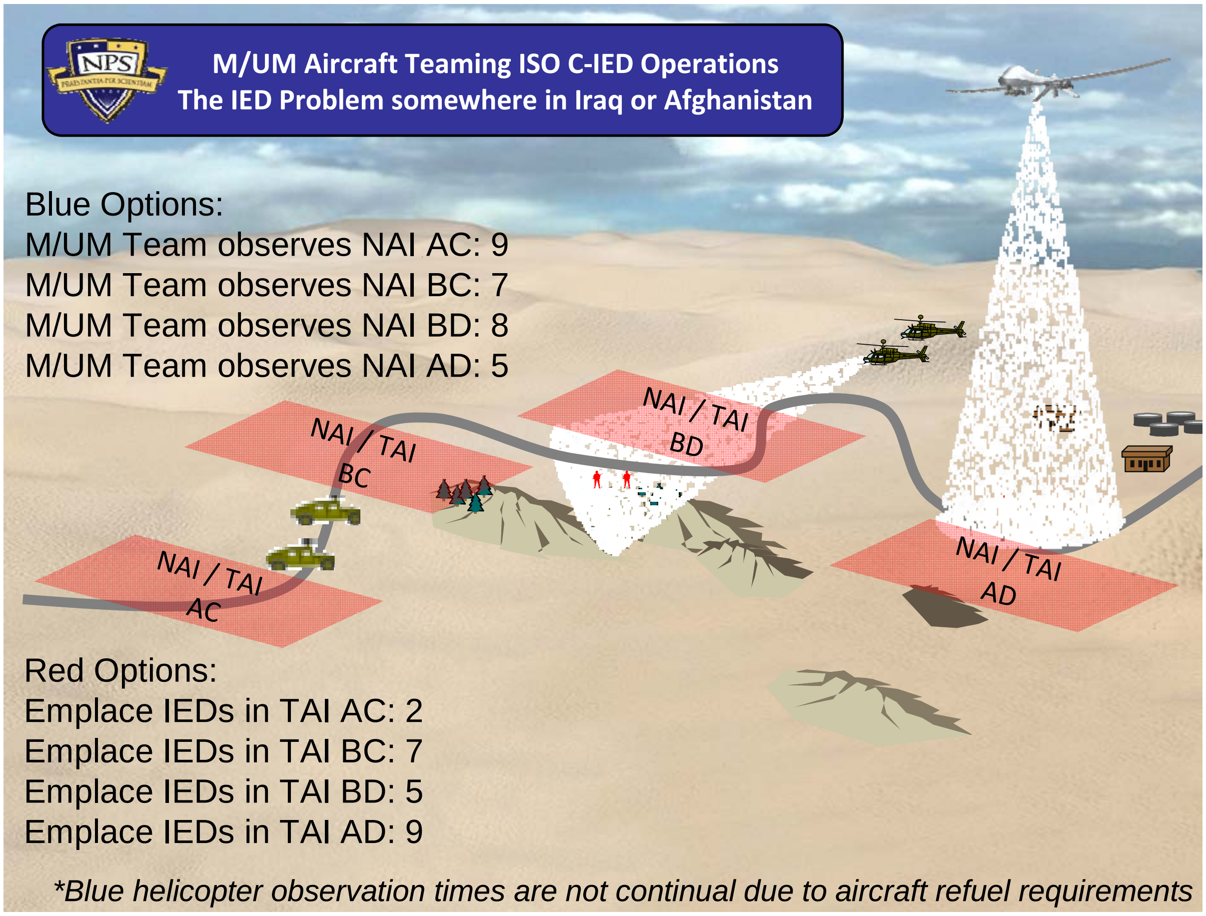

Figure 14. M/UM Aircraft Team (SWT and UAV) versus IED emplacers

The values associated with each scenario are equal to percentage of success and scaled from 1 to 10 or 10 percent to 100 percent success rate. All values are based on each area of operation (NAI/TAI) using Mission, Enemy, Terrain, Troops available, Time, and Civilian considerations (METT-TC) as the determining factor for the listed numerical value.

The assumptions used for this game are as follows.

- Red’s objective is to achieve the highest possible probability of successfully attacking Blue while Blue’s objective is to minimize it
- Red’s gain is Blue’s loss and vice-versa
- Both sides move simultaneously without communication
- Both sides know game matrix

- The probability of Red's success does not change for the duration of the game
- Each player's best strategy is his or her optimal strategy
- Game occurs over a 24-hour period—day/night
- Values based on percentage of success using METT-TC analysis/considerations

C. THE ANALYSIS

For a graphical depiction of the analysis of the game model, please see the Appendix. The analysis determines what the optimal strategies are for both blue and red forces. It also includes likely outcomes, security levels, and prudential strategies for both forces.

D. CONCLUSION

In all three partial sum game scenarios, Blue Forces should observe NAI BD. Blue has no first move, and there is no Nash Equilibrium. Scenario one, Blue's value of the game, is 6.3. Blue should play A 16.67 percent and B 83.33 percent when Red plays C 66.67 percent and D 33.33 percent. Scenario two, Blue's value of the game, is 5.8. Blue should play A 20 percent and B 80 percent when Red plays C 60 percent and D 40 percent. Scenario three, Blue's value of the game, is 7.4. Blue should play A 20 percent and B 80 percent when Red plays C 60 percent and D 40 percent.

In all three partial sum game scenarios, Red Forces should target TAI BD. Red has a first move; however, there is no Nash Equilibrium. Also, in all three scenarios, Red's value of the game is 5.8, and should play C 44.44 percent and D 55.56 percent when Blue plays A 22.22 percent and B 77.77 percent.

The likely outcomes for each scenario are as follows.

- UAV vs. IED emplacers—7, 5 BD
- SWT/AWT vs. IED emplacers—5,5 BD
- M/UM Team vs. IED emplacers—— 8,5 BD

In summary, Blue Forces have a much better chance of observing Red Forces utilizing the M/UM Aircraft Team (scenario three). Blue should focus reconnaissance efforts on NAIs BC and BD (80 percent of the time) and NAIs AC and AD (20 percent of the time) for a 74 percent chance of success. Red Forces in all three scenarios should target Blue Forces at NAIs AC and BC (44.4 percent of the time) and NAIs AD and BD (55.5 percent of the time) for a 58 percent chance of success.

This type of game model can be utilized in the conduct of RSTA operations to assist in the defeat of IED networks, as well as other targets of interest. As discussed in previous chapters, constraints, such as rugged and steep terrain, distributed forces, and limited resources, can be overcome by teaming M/UM aircraft. Using M/UM aircraft as network relay nodes, as well as a maneuver team, increases the commander's situational awareness and kinetic, and non-kinetic effects on the battlefield. This game theory model can be used in combat and training to assist in resource distribution and allocation based on the enemy situation.

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VII. CONCLUSION

> Just as the advent of airpower and the helicopter during the twentieth century revolutionized the conduct of modern warfare, the advent of unmanned aircraft has significant implications on the conduct of warfare for the decades to come.[60]

Since the beginning of the GWOT, UAS have truly evolved and transformed the way the U.S. fights within both the Army and joint forces. The Battle of Sadr City in March through April of 2009, and the 25th CAB's utilization of the TTP during combat in Iraq, verify the effectiveness of teaming M/UM aircraft. Whether using the TTP for over the horizon voice communication and network relay or conducting RSTA operations, the combat lethality and situational awareness provided to the ground commander is unquestionable.

"Unmanned systems seem to offer several ways of reducing the mistakes and unintended costs of war."[61] The positive factors of M/UM aircraft teaming are the following.

- Agility
- Endurance
- Increased Operational Tempos
- Increase Situational Awareness
- Lethality
- Network and Voice Communications Over the Horizon Capability
- Persistent Reconnaissance & Surveillance
- Reliable Combat Information
- Risk Mitigation for the Dull, Dirty, and Dangerous Missions
- Survivability

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[60] Carlile and Larese, "Manned-Unmanned Aircraft Teaming Making the Quantum Leap."

[61] Singer, *Wired for War: The Robotics Revolution and Conflict in the Twenty-first Century*, 397.

Some negative factors are associated with M/UM aircraft teaming. The TTP provides the ground commander with real time situational awareness that can sometimes lead to "misunderstanding from afar."[62] The resultant is sometimes untimely supervision from the TOC that dilutes the situational awareness and authority of the leader on the battlefield. Additionally, observation of the FMV from the TOC can sometimes be deceiving and can cause issues, as the complete ground operation picture is not truly depicted. Both of these aforementioned negative factors can be corrected with training, experience, and knowledge of the limitations and capabilities of the systems.

> General Petraeus stated, "What we need from Congress: more ISR assets, and also full funding of Find, Fix, Finish, Exploit, Access and Disseminate (F3EAD). Inside the DoD, we must also institutionalize elements of this, including the ad-hoc arrangements out there currently in use. We must capture it all in doctrine, training, institutions, etc. This needs to be taught in all our school houses, at the intelligence center, the aviation center, the fires center. Maneuver leaders must learn how to exploit these assets.[63]

Recommendations for future implementation, and execution of M/UM aircraft teaming appear in the Doctrine, Organization, Training, Materiel, Leadership and Education, Personnel and Facilities (DOTMLPF) format listed below.

- **Organization:** All Army UAS should be placed under the control of the CABs to provide direct support to the BCTs in a more efficient and effective manner. The task organization of all UAS under the CAB provides UAS companies with experienced aviation leadership in operations, maintenance, and safety.
- **Doctrine:** All doctrine should be updated to include M/UM aircraft teaming. This should include Regulations, Joint Publications, Field Manuals, Aircrew Training Manuals for both manned and unmanned aircraft, and Training Circulars.
- **Training:**
    - UAS and manned aircraft crews should conduct virtual reality training, which is being developed through the Department of Systems Engineering at the United States Military Academy (USMA), USARPAC, and USAACE

[62] Singer, *Wired for War: The Robotics Revolution and Conflict in the Twenty-first Century*, 351.

[63] Petraues, C-SPAN video briefed at the U.S. Military & Foreign Policy World Affairs Council.

- UAS and manned aircraft crews should routinely train together using the TTP
- UAS and manned aircraft crews should conduct live fire exercises to verify laser designation and engagement qualifications
- UAS and manned crews should conduct M/UM aircraft teaming at CTCs
- Staffs should learn through CTCs and home station training to incorporate the TTP during planning/Military Decision Making Process (MDMP) not just for kinetic and non-kinetic effects but also as a combat enabler

- **Material:**
  - Continued research in this domain should be aggressively pursued
  - All UAS and manned aircraft should be equipped with the most current Mission Equipment Packages (MEP) available
- **Leadership and Education:**
  - Commanders at all levels should be briefed on the capabilities, limitations and successes and failures of the TTP to include the C2 complexities
  - All soldiers should understand the capabilities of UAVs
- **Personnel:** UAS companies should be manned with intelligence and operations personnel, as well as aviation maintenance, and safety personnel to enhance daily operations.
- **Facilities:**
  - Division airfields should be readied for receipt of the Sky Warrior
  - CTCs and live fire ranges should plan and build the infrastructure for UAS operations

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APPENDIX.

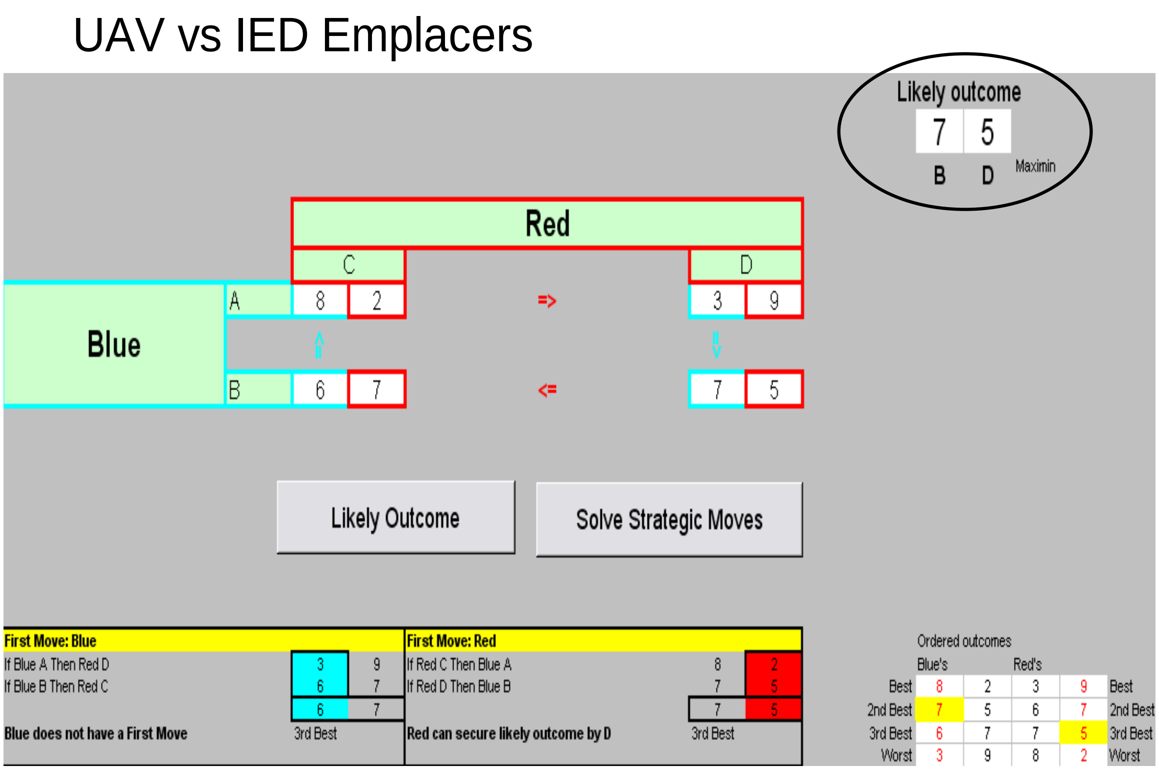


Table 1. UAV versus IED emplacers, scenario one, partial sum game outcome

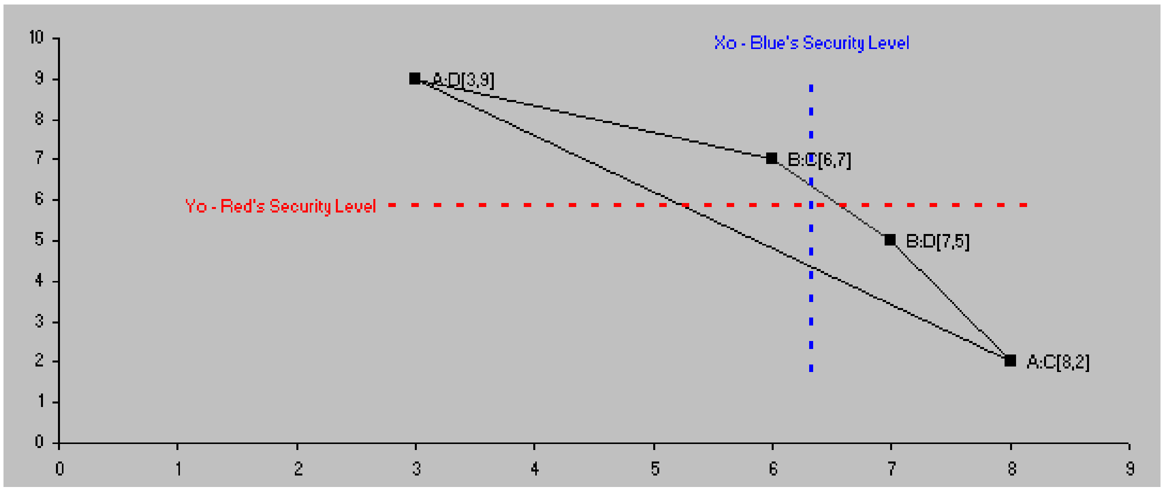


Table 2. UAV versus IED emplacers, scenario one, partial sum game, security level outcome

Blue - Prudential Strategy - Solution

Blue's Game
Blue Maiximizing
Red Minimizing the opponent's payoff

Zero-Sum Game with Blue's Payoffs (blue)

		Red		
		C		D
	A	8	=>	3
Blue		/\ ‖		‖ \/
	B	6	<=	7

6.333333

Solution in the Pure Strategy: No — **Value of the Game: 6.333333** 6 1/3

Solution in the Mixed Strategy: Yes — **Blue's Security level**

Blue should play (Blue - Prudential Strategy)

A	**16.67%**	**% of the time and**	1/6
B	**83.33%**	**% of the time**	5/6

When Red plays

C	**66.67%**	**% of the time and**	2/3
D	**33.33%**	**% of the time**	1/3

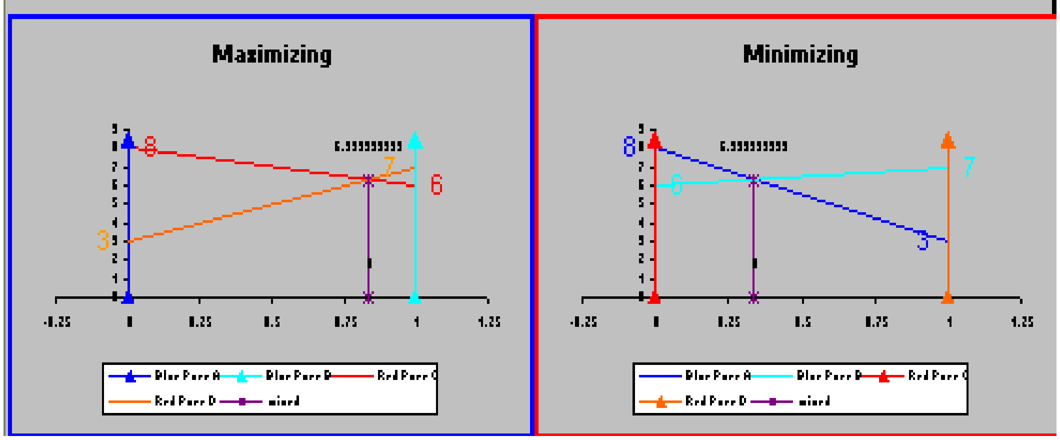


Table 3. UAV versus IED emplacers, scenario one, partial sum game, Blue Forces prudential strategy

Red - Prudential Strategy - Solution

Red's Game
Red Maiximizing
Blue Minimizing the opponent's payoff

Zero-Sum Game with Red's Payoffs (red)

		Red		
		C		D
	A	2	=>	9
Blue		⇑		⇓
	B	7	<=	5

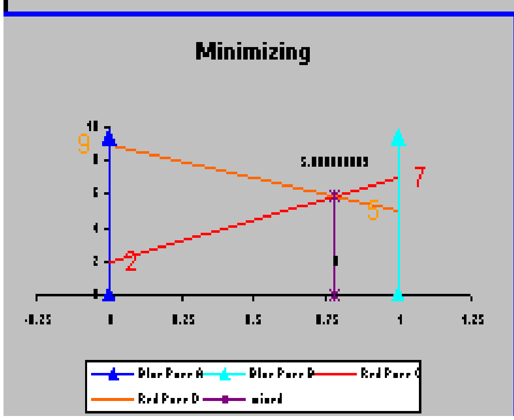
			5.888889	
Solution in the Pure Strategy:	No	**Value of the Game:**	**5.888889**	5 8/9
Solution in the Mixed Strategy:	Yes		**Red's Security level**	

Red should play (Red - Prudential Strategy)

C	**44.44%**	**% of the time and**	4/9
D	**55.56%**	**% of the time**	5/9

When Blue plays

A	**22.22%**	**% of the time and**	2/9
B	**77.78%**	**% of the time**	7/9



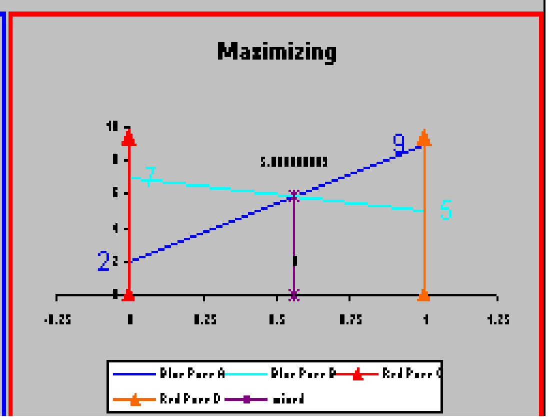


Table 4. UAV versus IED emplacers, scenario one, partial sum game, Red Forces prudential strategy

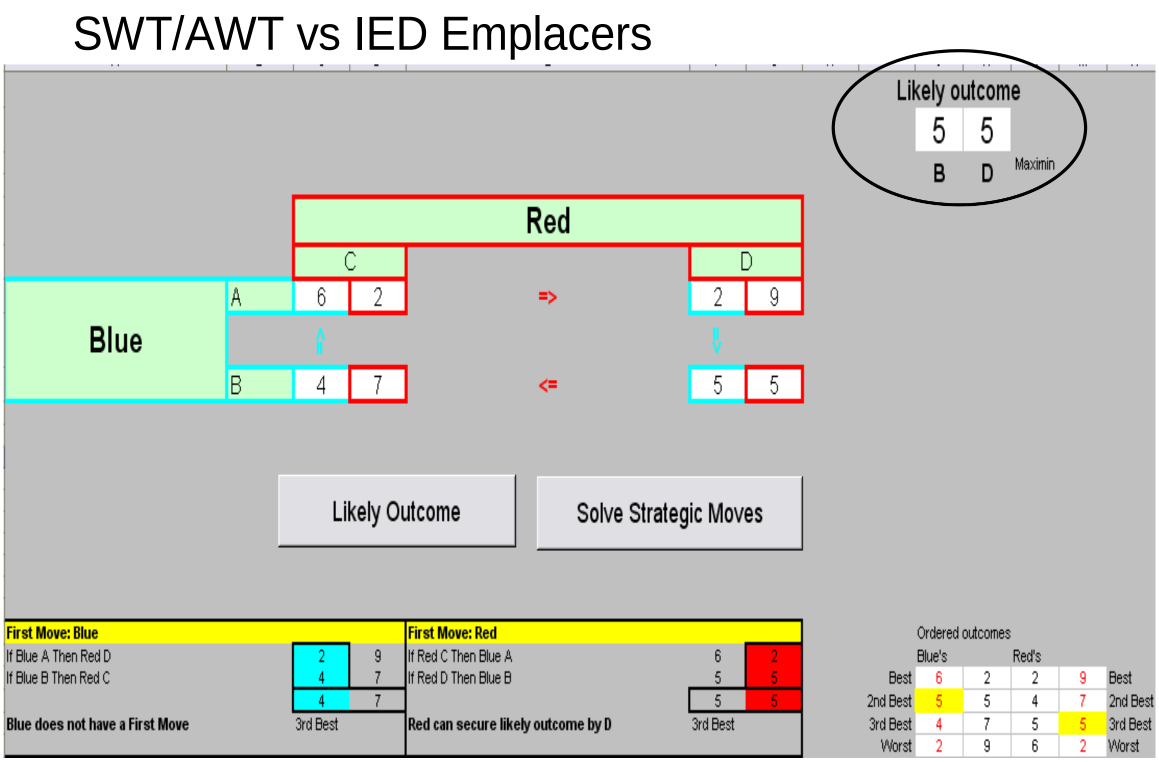


Table 5. SWT/AWT versus IED emplacers, scenario two, partial sum game outcome

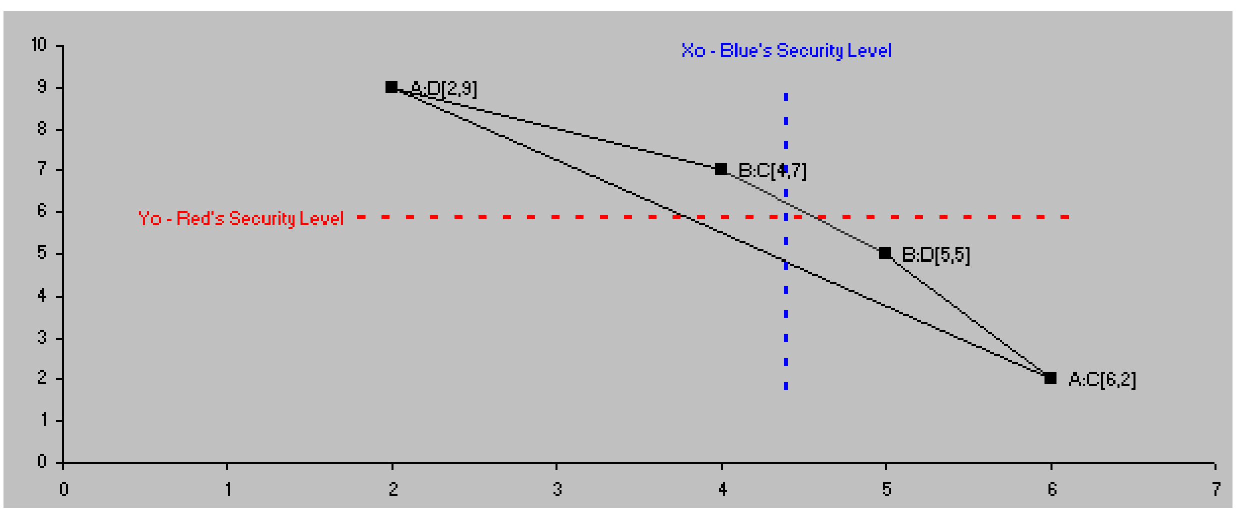


Table 6. SWT/AWT versus IED emplacers, scenario two, partial sum game, security level outcome

Blue - Prudential Strategy - Solution

Blue's Game
Blue Maiximizing
Red Minimizing the opponent's payoff

Zero-Sum Game with Blue's Payoffs (blue)

			Red	
		C		D
	A	6	=>	2
Blue		⇑		⇓
	B	4	<=	5

4.400000

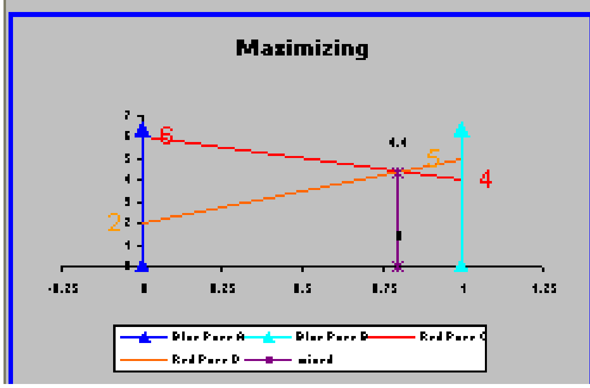
Solution in the Pure Strategy: No — **Value of the Game:** **4.4** 4 2/5
Solution in the Mixed Strategy: Yes — **Blue's Security level**

Blue should play (Blue - Prudential Strategy)

A	**20.00%**	**% of the time and**	1/5
B	**80.00%**	**% of the time**	4/5

When Red plays

C	**60.00%**	**% of the time and**	3/5
D	**40.00%**	**% of the time**	2/5



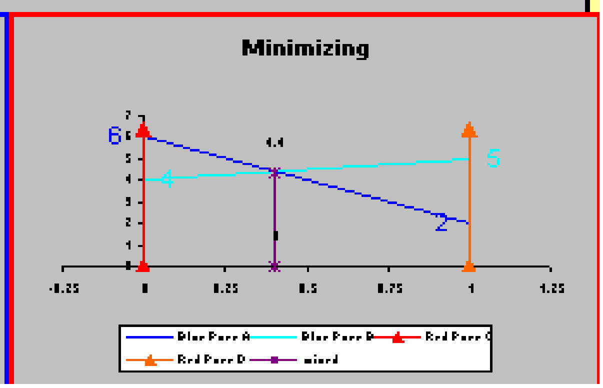


Table 7. SWT/AWT versus IED emplacers, scenario two, partial sum game, Blue Forces prudential strategy

Red - Prudential Strategy - Solution

Red's Game
Red Maiximizing
Blue Minimizing the opponent's payoff

Zero-Sum Game with Red's Payoffs (red)

			Red	
		C		D
	A	2	=>	9
Blue		⇑		⇓
	B	7	<=	5

5.888889

Solution in the Pure Strategy: No — **Value of the Game: 5.888889** 5 8/9

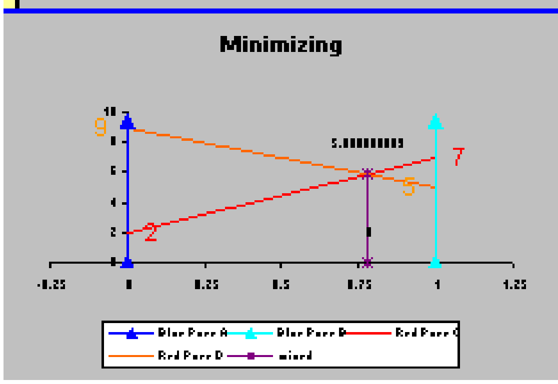
Solution in the Mixed Strategy: Yes — **Red's Security level**

Red should play (Red - Prudential Strategy)

C	**44.44%**	**% of the time and**	4/9
D	**55.56%**	**% of the time**	5/9

When Blue plays

A	**22.22%**	**% of the time and**	2/9
B	**77.78%**	**% of the time**	7/9



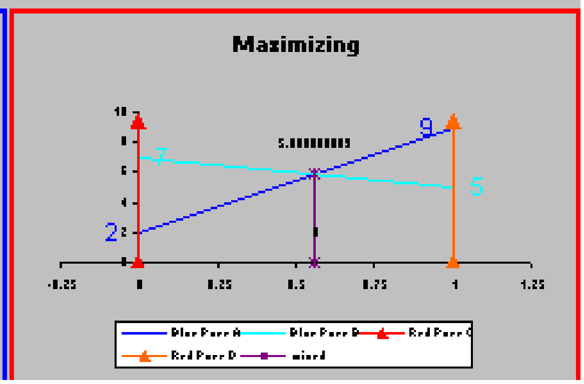


Table 8. SWT/AWT versus IED emplacers, scenario two, partial sum game, Red Forces prudential strategy

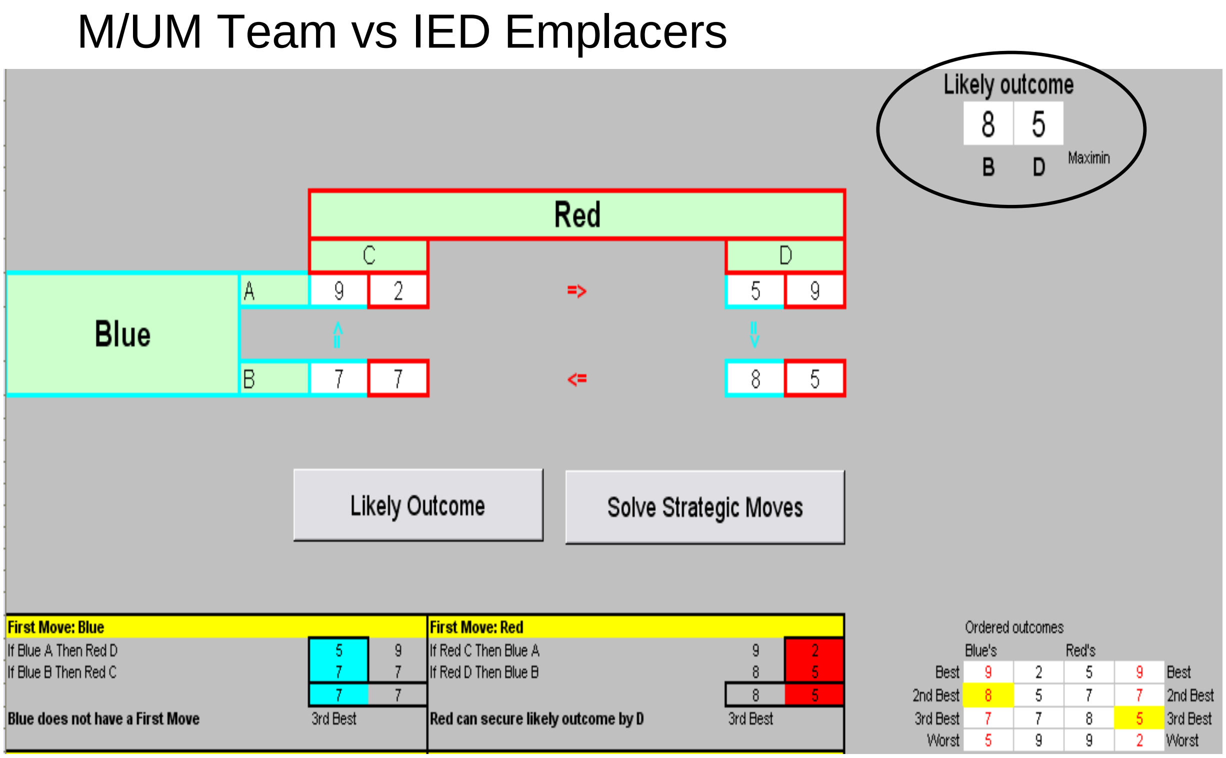


Table 9. M/UM Aircraft Team versus IED emplacers, scenario three, partial sum game outcome

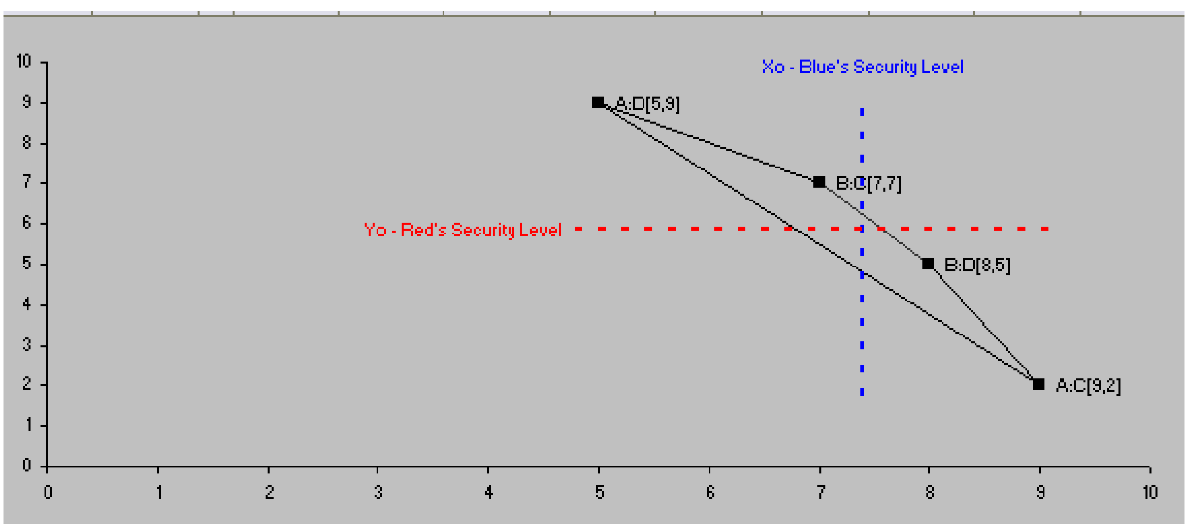


Table 10. M/UM Aircraft Team versus IED emplacers, scenario three, partial sum game, security level outcome

Blue - Prudential Strategy - Solution

Blue's Game
Blue Maiximizing
Red Minimizing the opponent's payoff

Zero-Sum Game with Blue's Payoffs (blue)

			Red	
		C		D
	A	9	=>	5
Blue		⇑		⇓
	B	7	<=	8

7.400000

Solution in the Pure Strategy:	No	**Value of the Game:**	**7.4**	7	2/5
Solution in the Mixed Strategy:	Yes		**Blue's Security level**		

Blue should play (Blue - Prudential Strategy)

A	**20.00%**	**% of the time and**	1/5
B	**80.00%**	**% of the time**	4/5

When Red plays

C	**60.00%**	**% of the time and**	3/5
D	**40.00%**	**% of the time**	2/5

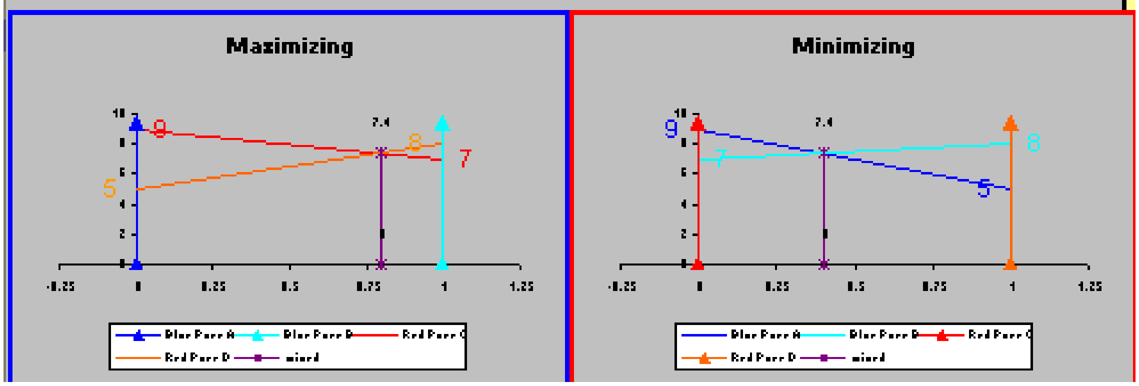


Table 11. M/UM Aircraft Team versus IED emplacers, scenario three, partial sum game, Blue Forces prudential strategy

Red - Prudential Strategy - Solution

Red's Game
Red Maiximizing
Blue Minimizing the opponent's payoff

Zero-Sum Game with Red's Payoffs (red)

		C		D
		Red		
	A	2	=>	9
Blue		⇑		⇓
	B	7	<=	5

Solution in the Pure Strategy: No

Solution in the Mixed Strategy: Yes

5.888889

Value of the Game: 5.888889 5 8/9

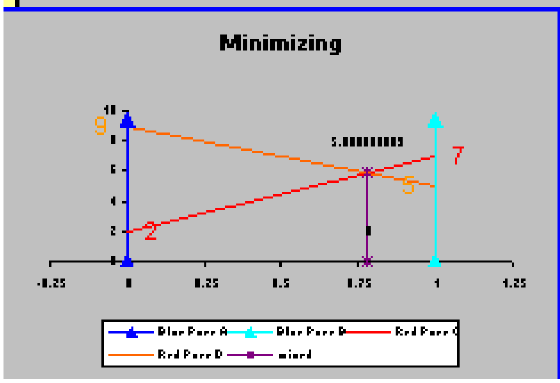
Red's Security level

Red should play (Red - Prudential Strategy)

C	**44.44%**	**% of the time and**	4/9
D	**55.56%**	**% of the time**	5/9

When Blue plays

A	**22.22%**	**% of the time and**	2/9
B	**77.78%**	**% of the time**	7/9



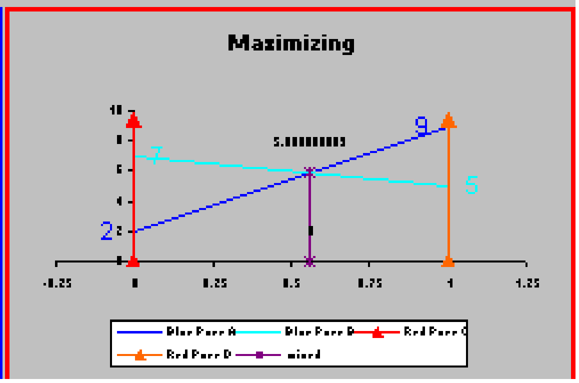


Table 12. M/UM Aircraft Team versus IED emplacers, scenario three, partial sum game, Red Forces prudential strategy

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14. Tim Strabbing
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15. Chris Kluckhuhn
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16. Kelly Hanlon
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